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A Research about Wear Process of Details from Belt Conveyor

Iliya Todorov

Abstract: *The recent paperwork accents to wear process of details working within belt conveyor designed as rotating grill as part of Central Pump Station 3,4 working in a coastline pump station of AES – Kozloduy. It is established so the wear along outer diameter of the driving roller complies to a normal law of distribution while wear along inner diameter complies to an exponential law of distribution. The wear factor value at front and rear sections of the roller obeys to Weibull's law of distribution. The results presents that outer diameter of roller has nearly 10-times higher wear compared to the ones measured along its inner diameter and width. The wear factor value at both – front and rear section of the roller is almost equal along all measured points.*

Key words: *belt conveyor, wear factor value, details*

INTRODUCTION

The major part of belt conveyor structure elements which could be restored belongs to the group of cylindrical centered or rotating details made of steel or iron as their working surfaces most often rely on requirements regarding hardness, accuracy and cleanliness, having complex structure and higher value. The wear factor value for such type of details depending of working condition is quite variable ranging from 0.5 mm up to 10 mm. [2-5]

The process of reconditioning of worn details from belt conveyors provides a significant economy of materials, energy, fuel and labor as well as rational consumption of natural resources and protection of the environment [10, 11]. The selection of rational method for reconditioning of such details, requires an accurate determination of the type of wear process and wear factor value depending of actual working conditions.

The aim of recent paperwork is to establish the character of distribution of wear during examination of details from belt conveyors at point of further selection of an appropriate method for reconditioning.

MATERIALS AND METHODS

The belt conveyors found their wide usage in different spheres of the economy as agriculture, industry, energetic, etc. The overall condition of their structural elements affects not only to their interaction with the load, but to efficiency and reliability to whole conveyor [1, 7, 8]. A large number of factors appear to have a significant influence to such details, related to working conditions, type and level of loading, speed regime and others, leading to their wear and tear. The character and value of the wear factor affects further selection of method, working regime and conditions for their reconditioning [3, 6, 8, 9, 12].

An object of our examination is a rotating grill of central pump station CPS – 3,4 working in a coastline pump station at AES – Kozloduy. It is designed to clean the incoming water from Danube, which is a regular carrier of tree branches, sheets and other rough impurities. The working conditions would be considered as very heavy, since there is a serious hydro-abrasive wear, caused by presence of billions of abrasive particles of sand in the passing water as well as active corrosion while the grill is out of charge.

We have been asked about reconditioning of friction pairs of the grill, acting as a driving roller, which moves a rotating grill-shaped metal belt. Initially, the structural characteristics of worn details are determined in order to create the model and method selection. The surface quality and wear resistance depends of selected method as well as wear resistance influences the durability of the reconditioned detail. According the recent requirements and trends, the durability and wear resistance of reconditioned details must be at least equal to the same of produced ones [8, 9, 11, 12].

RESULTS AND DISCUSSION

To select an appropriate method for reconditioning as well as regime parameters and working conditions, it is necessary to determine the parameters of the wear factor at point of value, character and distribution. For such purpose, measurements of 135 rollers and 75 axes were done.

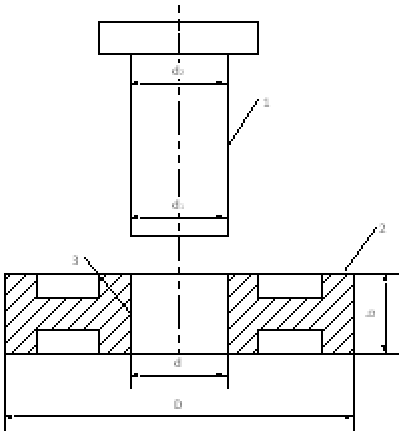

Fig. 1 Object of examination

1 – axis; 2 – outer surface of the roller; 3 – inner surface of the roller

The measurements were done at both ends of the friction surfaces of rollers and axes as the scheme is shown at Fig.1. Each axis was measured at both typical zones – at front and rear part, but the roller – along both typical zones – outer and inner surfaces defined by D and d marks on Fig.1.

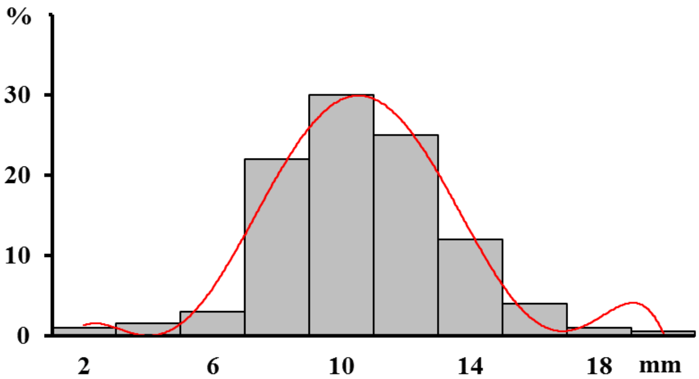

Fig. 2 Distribution of the wear factor value along outer diameter of the roller

According to obtained results through basic statistical functions, the graphs of wear factor distribution are presented on Fig.2 to Fig.6.

The results related to wear factor along outer diameter of the roller are presented on Fig.2. It is visible that distribution of the wear factor belongs to the normal law of distribution as the spread ranges from 0.1 mm to 20 mm. The distribution presents that the most common is wear factor at rate of 10 mm and such rate belongs to 30% of the examined rollers. Around 80 to 90% among all rollers have wear factor value within range of 6 to 14 mm. Very minor part among all 135 rollers have wear factor within range of 2 to 4 mm and 16 mm or more.

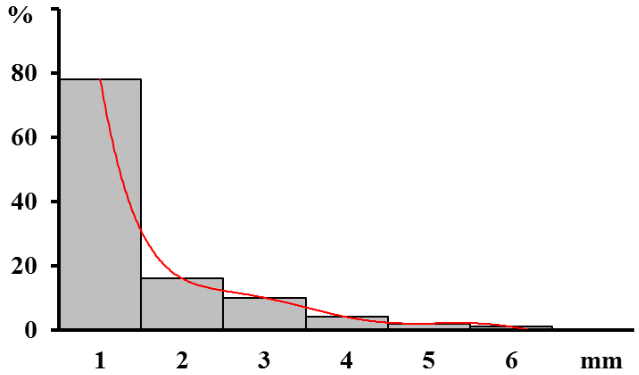

Fig. 3 Distribution of the wear factor value along inner diameter of the roller

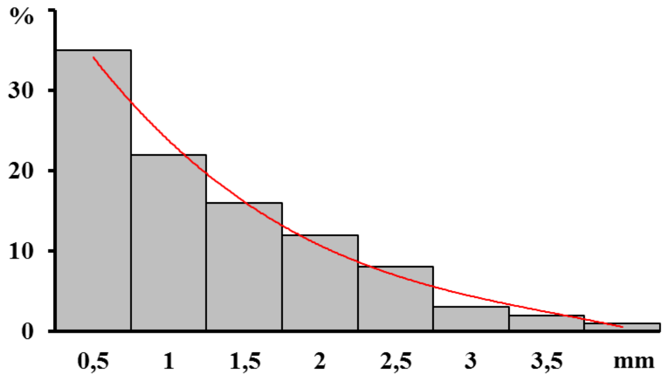

Fig. 4 Distribution of wear factor value along the width of the roller

The wear factor value along inner diameter of the roller has an exponential character of distribution as seen on Fig.3 as the spread range is within rates from 0.1 mm up to 7 mm. Almost 96% of all examined rollers have wear factor value within range between 0.1 to 3 mm. 78% of the rollers has a wear factor value up to 1 mm as most of them belongs to 0.1-0.5 mm range. Analogical character of distribution is noticeable to wear factor along the width of the roller (Fig.4.)

As seen at Fig.4, the range spread is within range from 0.1 mm up to 4 mm. Most of the rollers (35%) have side wear at rate of 0.5 mm, but 90% among all wears within range from 0.5 mm to 2.5 mm.

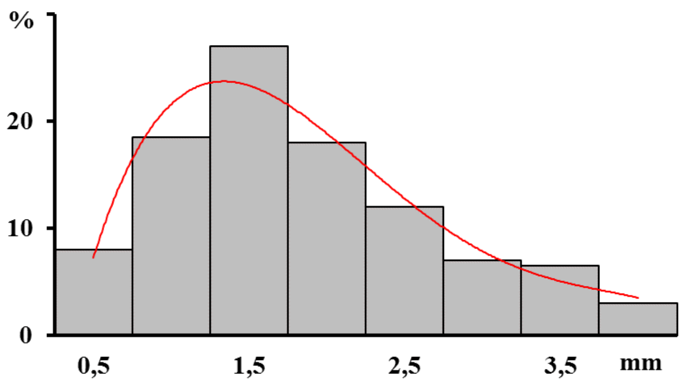

Fig. 5 Distribution of wear factor value along rear section of the axes

The wear factor along both – front and rear sections of the axes have a distribution according Weibull's law as the range spread is within rates from 0.1 mm to 4 mm as seen on Fig.5 and Fig.6. The most common wear factor value is the rate of 1.5 mm as such rate is noticeable for 30% of the rollers related to the rear section of the axes, but 35% related to the front sections. For both section is visible that 70-80% of the axes have wear factor value between 1 mm and 2.5 mm as the distribution at Fig.5 is more uniform.

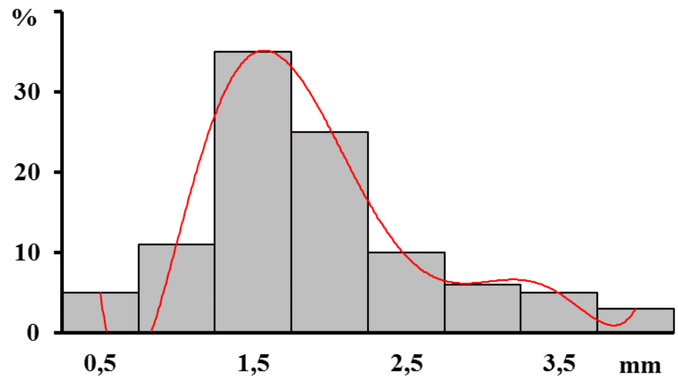

Fig. 6 Distribution of wear factor value along front section of the axes

The main statistical parameters (average value, mode, median, maximal value, minimal value and ovality of geometrical shape) of wear factor of friction surfaces are presented in table 1. Highest average value of wear is noticeable along outer diameter of the roller (10 mm), but lowest value of 0.76 mm relates to wear factor along the width. The average wear factor along inner diameter of the roller is 1 mm, which is 10 times less than the one along its outer diameter. This may be explained by different working conditions of both surfaces, related mostly to the presence of different amount of abrasive particles between those surfaces and related frictional pairs.

The mode of wear factor along outer diameter of the roller is 30 times greater than the one along its inner diameter, but the median values for same surfaces shows a difference of around 100 units.

The minimal value of the wear factor is same to all surfaces, while the maximal value is different and ranges between 3.6 and 19 units. The ovality of frictional surfaces of outer and inner diameters is almost equal at rates of 0.6 and 0.5 mm at control sections.

Table 1. *Statistical parameters of wear factor of frictional pairs from roller conveyor*

№	Statistical parameters	Values				
		Roller			Axes	
		Outer diameter	Inner diameter	Width	Front section	Rear section
1	Average value	9,88	0,93	0,76	1,58	1,62
2	Mode	9	0,3	0,5	1,5	1,5
3	Median	10	0,1	0,1	2	2
4	Minimal value	0,1	0,1	0,1	0,1	0,1
5	Maximal value	19	7	3,8	3,6	3,8
6	Spread range	18,9	6,9	3,7	3,5	3,7
7	Ovality	0,6	0,5	-	0,1	0,2

The different values of wear factor along outer and inner diameters of the roller as well along its width requires selection of different working regime parameters of vibrating gas metal arc overlaying process during reconditioning of worn rollers from roller conveyor [6, 8, 9].

Because too large spread range of wear factor values at point of outer diameter of the roller, it was necessary to be sorted into four groups divided by 5 mm, but such was not needed before reconditioning of the roller along its inner diameter.

The wear factor values related to front and rear sections of the axes presents almost same statistical parameter values with some minor differences as seen at columns 6 and 7 at table 1, so thus gave an opportunity to select the same working regime along the whole length of the frictional surface [11].

CONCLUSION

1. The normal distribution of wear factor along outer diameter of the roller, exponential distribution of wear factor along inner diameter of the roller and its width as well as Weibull distribution along front and rear sections of the axis of frictional pair are established.
2. The outer diameter of the roller has a ten times greater wear compared to the ones along inner diameter and width of the roller.
3. The difference between maximal and minimal wear factor values is greatest along outer diameter of the roller and lowest along its width.
4. The wear factor values of all statistical parameters along front and rear sections of the axis of roller are almost equal.

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Analysis of Production Process

Miroslav Pristavka, Veronika Hrda, Hristo Beloev, Pavol Findura, Vladimir Krocko

Abstract: *In the paper we will deal with analysis and consequent application of statistical methods in quality management. We will describe adequate methodology and quality management by detection of a meter competence, production process and finding out the reasons of nonconforming steps in a production. The given suggestions of methods can significantly contribute to lower economic production aspects and individual position solutions of quality management in the Kongsberg Automotive s.r.o Vráble organization. Kongsberg Automotive has established quality management according to IATF 16949 norm by which they provide trust in competence of their processes, product quality and provides continuous improvement.*

Keywords: *statistical method, quality, analysis*

INTRODUCTION

Competition on the market tis huge and that is why every organization must resist threats from other organizations. If we want an organization to prosper on the market, we have to provide continuous management according to primary norms of quality management systems. Priority task of an organization is to perceive the needs of a customer, whether present or future and try to meet their requirements, or even surpass their expectations [2,5].
To produce quality, it is necessary to use statistical methods which help us to evaluate defectiveness of the given product. Statistical methods are nowadays very sought-after as they are important within various researches.

MATERIALS AND METHODS

The objective of the paper is to find out the reason of error occurrence on a component of a cylinder form, used within a control lever assembly produced in Kongsberg Automotive s.r.o Vráble. Organization focuses on spraying plastic parts and consequent production of a control lever [1]. Error evaluation will be performed based on found quantity by simple statistical methods, indexes of competence C_P and C_{PK} and by Minitab program as well [6,8].

Process of spraying is automatic. Technology is adequate for small series as well as large series production and belongs to wasteless technologies. Processed plastic is molten in a melting chamber and a melt of plastic is injected by piston into closed cool form.

Procedure of spraying:

- melting,
- injection of a part,
- cooling,
- ejection of a part.

Pareto diagram

Procedure within creation of Pareto diagram:

1. Selection of severe issue
2. Selection of a time span of its occurrence to get a real image of a reality
3. Collection of data on the issue
4. Searching for possible causes of the issue by Ishikawa diagram
5. Quantification of a number of causes into a table
6. Drawing data into a bar graph: y axes - number of cases expressed by the height of a bar, x axes reasons descending from the number of cases
7. On the right side of the graph, creation of the second y axes with a cumulative relative multiplicity in %
8. Drawing the cases into a graph by cumulative curve
9. Documenting the results of the analysis and informing the interested [3,4].

Regulation diagram for average and range ($\bar{X}$, R)

Regulation diagram will be established 100% under control of fifty individual consecutive components the same cavity.

To construct it, we need to compute average value of a symbol in a sub-group and range in a sub-group. Average value of a symbol [7] in a sub-group is computed according to an equation:

$$\bar{X}_i = \frac{1}{n}\sum_{j=1}^{n} X_{ij} \tag{1}$$

where: i – serial number of a sub-group = 1, 2, ... k

j – serial number of a measured value in a sub-group = 1, 2, ... n

k – number of sub-groups

n – range of a sub-group

X_{ij} – measured value in an i sub-group

Range of a sub-group is computed according to an equation:

$$R_i = \text{MAX}\,(X_{ij}) - \text{MIN}\,(X_{ij}) \tag{2}$$

where: MAX (X_{ij}) and MIN (X_{ij}) are maximum and minimum measured value in an i sub-group.

It is important to compute average range $\bar{R}$ and an average of process $\bar{\bar{X}}$, as they create central straight lines (Control Line) – CL. In the graph they are displayed as full horizontal lines.

$$\bar{R} = \frac{1}{k}\sum_{i=1}^{k} R_i \tag{3}$$

$$\bar{\bar{X}} = \frac{1}{k}\sum_{i=1}^{k} \bar{X}_i \tag{4}$$

where: R_i and $\bar{X}_i$ are ranges and averages in an i sub-group.

Computing upper and lower regulation line for an average:

$$UCL_{\bar{X}} = \bar{X} + A_2.\bar{R} \tag{5}$$

$$LCL_{\bar{X}} = \bar{X} - A_2.\bar{R} \tag{6}$$

Computing upper and lower regulation line for a range:

$$UCL_{\bar{R}} = D_4.\bar{R} \tag{7}$$

$$LCL_{\bar{R}} = D_3.\bar{R} \tag{8}$$

where: A2, D3 and D4 are constants changing in relation to a range of sub-groups.

Standard deviation „sigma“ is computed according to equation:

$$\hat{\sigma} = \frac{\bar{R}}{d_2} \tag{9}$$

where: $\bar{R}$ is average range in sub-groups

d_2 is a constant changing in relation to range of a sub-group

Indexes of competence of a process C_P and C_{PK} are given by relation:

$$C_P = \frac{T}{6.\hat{\sigma}} \tag{10}$$

$$C_{PK} = \frac{USL - \bar{\bar{X}}}{3.\hat{\sigma}} \tag{11}$$

$$C_{PK} = \frac{\bar{\bar{X}} - LSL}{3.\hat{\sigma}} \tag{12}$$

where: C_P – index of competence of a process

C_{PK} – corrected index of competence of a process

T – difference between lower and upper tolerance line

USL – upper regulation line
LSL – lower regulation line
$\hat{\sigma}$ – standard deviation „sigma“
Minimum requirements on $C_P \geq 1{,}33$ and $C_{PK} \geq 1{,}33$.

RESULTS AND DISCUSSION

Nowadays processing of plastic is very popular in all the branches of engineering industry. The most used way of processing is spraying, using adequate granulate from which we prepare a melt. This one is transported into a shape cavity of a spraying form. After cooling of a molding a component falls out thanks to a bouncer on a form onto a belt. After controlling of quality, a selected worker continues in the next process [4].

A component (Fig. 1) is a part of a control lever and serves for a reverse gear. In the Fig. 2 a visualisation of a component is displayed.

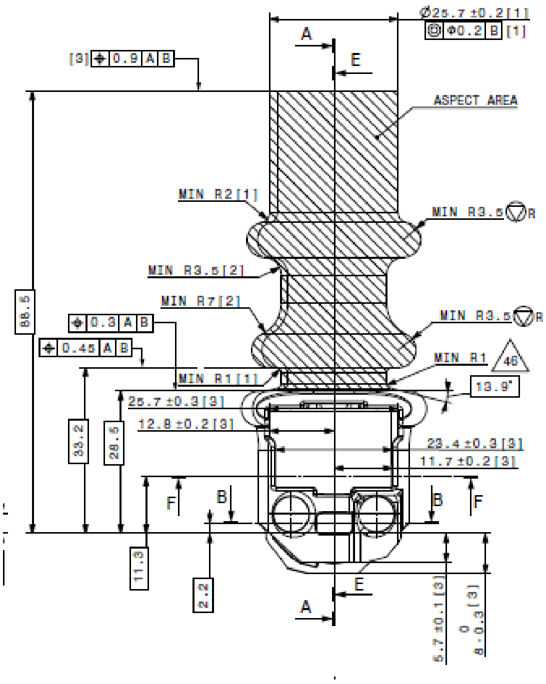

Fig. 1 A component 1000 601 797

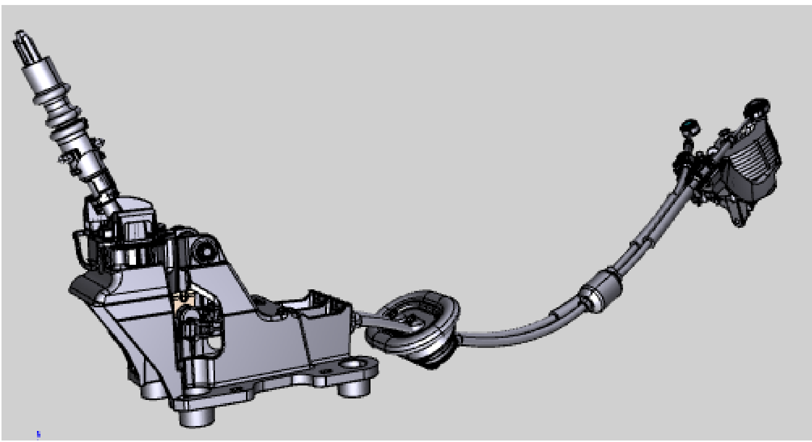

Fig. 2 Visualisation of a component 1000 601 797

Evaluation of Pareto diagram

Table 1. *Dependences of activities on mismatches*

Reason	n_j	$\sum n_j$	P_j (%)	$\sum P_j$ (%)
Silver lines, spots	231	231	70	70
Cracks	43	274	13	83
Scratches	21	295	6	90
Technological waste	16	311	5	94
Unfinished mold	10	321	3	97
Faulty material	5	326	2	99
Burn	2	328	1	100

Based on table 1 we created Pareto diagram (Fig. 3), according to percentage evaluation. Pareto analysis is an effective way of a detection of the most severe mismatches, which need to be monitored, it helps to decrease faults of a component and find the reason of a fault creation. The most common errors are silver lines and spots and we will solve this issue by the method of brainstorming.

In the Fig. 4 a component is displayed with the most common error, i.e. silver spot.

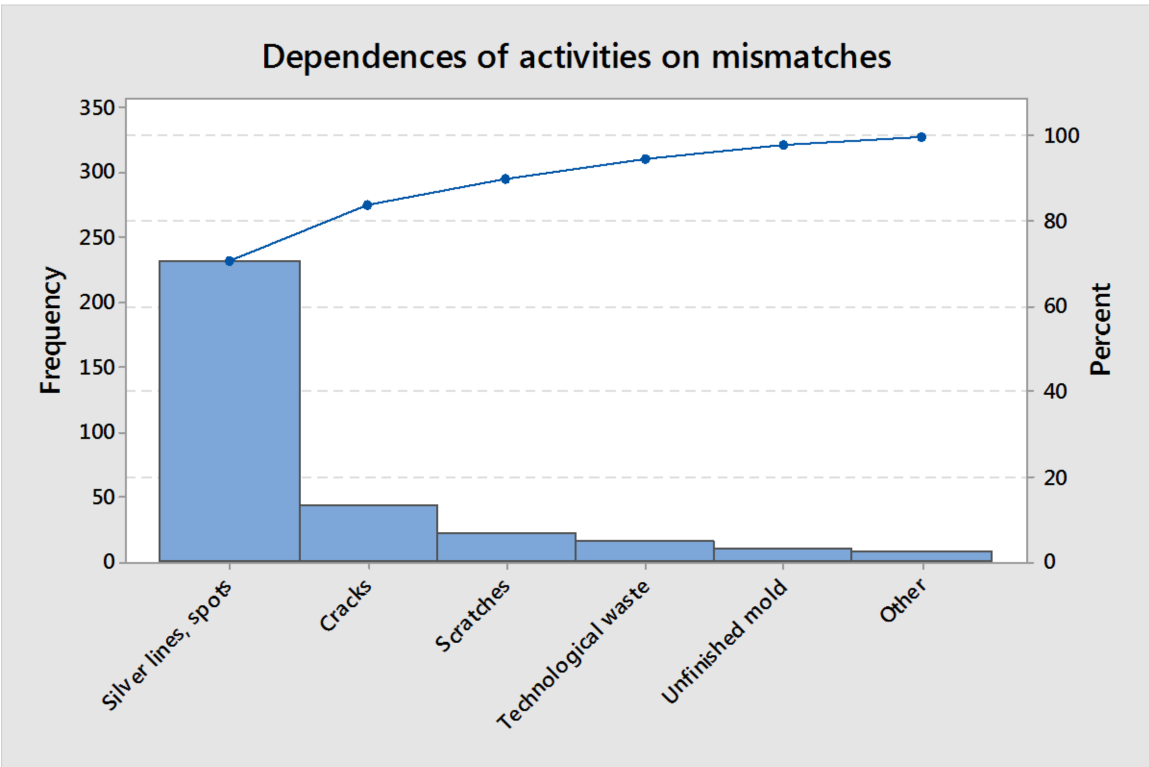

Fig. 3 Pareto diagram

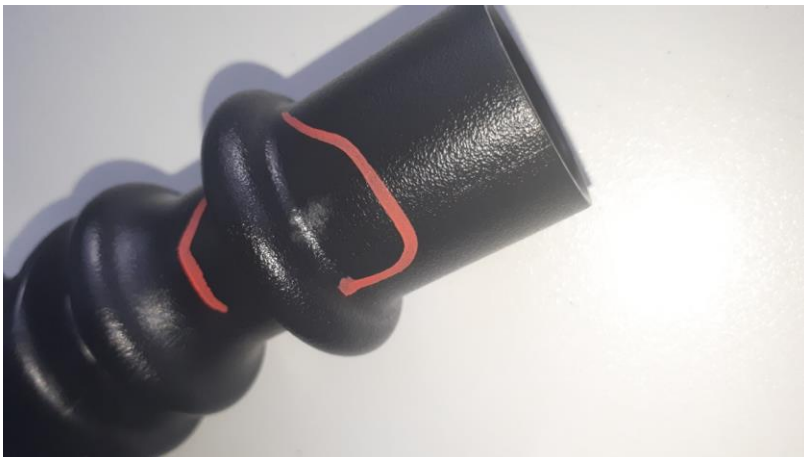

Fig. 4 Display of silver spot

We performed measurements of 50 pieces of cavity number one, the measured values were recorded in the table 2.

Table 2. *Measured values; mm*

Cavity 1			
Measures	**Values**	**Measures**	**Values**
1	25.72	26	25.71
2	25.72	27	25.71
3	25.64	28	25.65
4	25.63	29	25.65
5	25.6	30	25.64
6	25.64	31	25.72
7	25.71	32	25.77
8	25.57	33	25.72
9	25.56	34	25.71
10	25.55	35	25.66
11	25.68	36	25.63
12	25.76	37	25.69
13	25.73	38	25.71
14	25.69	39	25.65
15	25.77	40	25.67
16	25.71	41	25.6
17	25.68	42	25.72
18	25.7	43	25.64
19	25.7	44	25.68
20	25.64	45	25.66
21	25.71	46	25.67
22	25.73	47	25.63
23	25.7	48	25.66
24	25.72	49	25.59
25	25.72	50	25.69

To construct regulation diagrams it is important to compute average value $\overline{X}_i$ = 25,6762 mm and average range $\overline{R}_i$= 0,0439, as they form central lines in the graph. To create a graph, it is necessary to compute upper and lower regulation lines according to the determined equations. $UCL_{\bar{X}}$ = 25,7929 and $LCL_{\bar{X}}$ = 25,5595. For a range there are regulation lines $UCL_{\bar{R}}$ = 0,1434 and $LCL_{\bar{R}}$ = 0.

After computing all the values necessary for creation of a graph, we create a regulation diagram in a Minitab programme for average, in the figure 5 and for a range (Fig. 6).

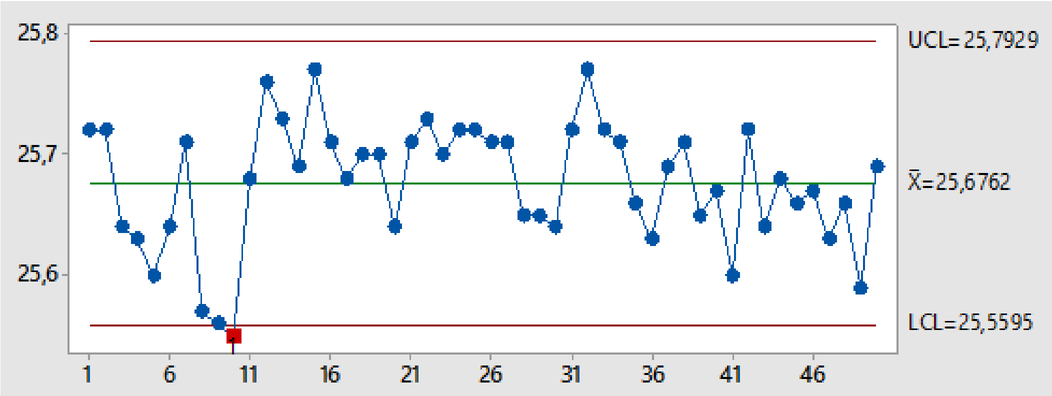

Fig. 5 Regulation diagram for an average

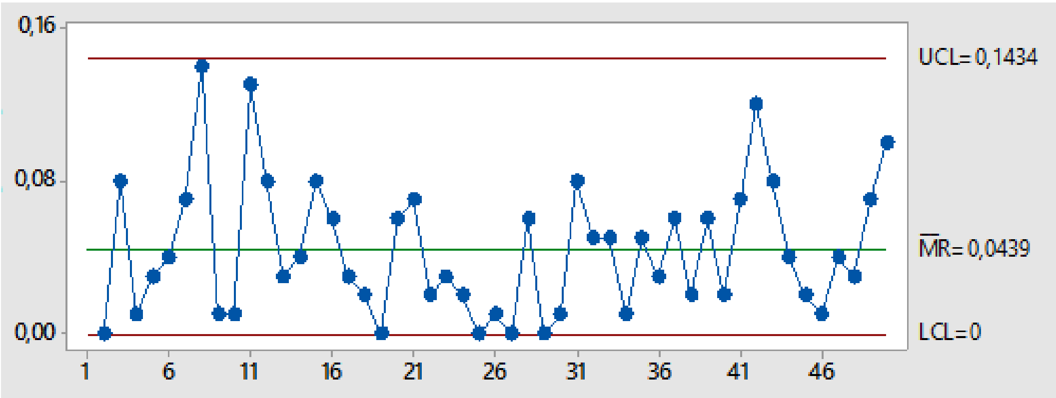

Fig. 6 Regulation diagram for a range

To find a competence of a process it is necessary to compute index of a process competence C_P a C_{PK}. C_P = 2,57 and C_{PK} = 2,37. As the indexes are ≥ 1,33, we may state that a process is competent, thus, it is under a statistic control [4].

CONCLUSION

Nowadays, every organization should realize, how important it is to produce quality components and provide quality service, as competition on the market is huge.

The objective of the paper was to evaluate fault on a plastic component of a cylinder form, serving for a reverse gear, especially because of common visual errors. As a visual control and measurement of a component are needed often, we suggested and produced a calibre for measuring this hole, which is timely effective.

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Analysis of Quality Management System Audit in a Selected Organization

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Abstract: *The objective of the paper is to show a process of internal audit of quality management system in a selected production organization and analyse it. Internal audit was performed according to the technical norm ISO IATF 16949:2016. Internal audit of a system was elaborated in a production organization focused on automobile components. First, we analysed time schedule of internal audit system. Audit was divided into three days. We audited branch in Trnava and two branches in Levice. After audit we elaborated a report from the internal audit where findings were registered during audit. These were divided to the main variations, fine deviations and potentials for improvement. Within audit we found one main deviation in Levice, in the branch called Géňa risk analysis for all the production processes (process FMEA) was not elaborated. For this deviation and for other fine deviations we made a catalogue of corrective actions. These are necessary to be implemented into processes of organization. We also made a catalogue of actions for improvement potentials, which enable us to gain higher effectiveness of production processes.*

Key words: *internal system audit, quality, quality management system, ISO IATF 16949.*

INTRODUCTION

People have focused on products meeting their personal requirements. Nowadays, all the organizations have set up quality management systems. The expression quality management system nowadays might also be a marketing move. Quality management systems are defined by a set of norms ISO 9000. It is important to improve and implement this system. To make it effective enough, though, it is necessary to continuously improve it and control it. And that is what quality management system audit serves us for [9,11].

The expression audit can simply mean a specific control of a subject or system. Quality management system audit serves us for systematic, regular research of effectiveness and effectivity of quality management system and looking for opportunities for continuous improvement [1,12]. The basic norm for quality management system audit is STN EN ISO 19011:2012 norm, the manual for quality management system audit or system of environmental management. Organizations focused on automobile production and production of their components are audited according to a technical norm ISO IATF 16949:2016. Audits are performed in the internal or external form, whilst we can perform audit for an individual product or the whole process [3,4,10].

MATERIAL AND METHODS

Quality management system is now inseparable part of customers´ imagination about quality. For an organization it is important to have working and effective quality management system. To confirm effectiveness of a set up quality management system we may use the internal audit of the system [5].

The objective of the paper is to describe and practically display the process of internal system audit in a production organization. Internal audit provides us with a picture describing how an audited system in an organization fulfils requirements of ISO IATF 16949:2016 norm. Furthermore, it is necessary to describe a time plan and audit schedule, which shows us the overall imagination about performed internal audit. It is important to process a report about audit after performing internal audit in an organization with findings recorded during audit [14]. Consequently, a catalogue of corrective actions for the shortcomings of the organization´s branches, is processed from a report on audit. These actions are then implemented from the catalogue into processes in an organization and verify them [6, 13].

Time plan of audit

Analysed audit of quality management system was done in an organizational unit of a production organization in Slovakia in Trnava and in Levice. It is internal audit of system. The objective of this internal audit in an organization was to receive a proof of permanent utilization of quality management system and confirmation of fulfilling requirements on certification according to a new norm ISO IATF 16949:2016, which replaced the old norm ISO TS 16949.

A place of internal audit of system wa a branch in:

- Trnava – production, machining parts and assembly,
- Levice: branch Géňa – machining of parts and branch Levitex – production and machining.

Auditor team was made of the head auditor and assistant auditor. Internal system audit in an organization is made based on pre-set time plan of audit which is done by a quality manager. Audit plan is clearly divided according to chronology of performing audit from the beginning till the end. Internal audit of quality management system is performed regularly once a year. Within internal audit according to IATF 16949:2016 norm, we audit specific branches and processes according to selected parts of the norm, not according to the whole norm.

RESULTS AND DISCUSSION

Characteristics of the organization

The organization was established in 1915 by Maag and Alfred Colsman. It is a worldwide technological leader in technique of propulsion and chassis, as well as in the area of passive and active security technique. The organization employs approximately 146 000 employees and it is made of 230 branches in almost 40 countries. In 2017 it reached a turnover of 36,4 billion euro. The company belongs to the biggest sub-contractors of automobile industry in the world.

The headquarters of the company are in Trnava, Slovakia. In Slovakia, it has five production localities – in Trnava, Levice, Šahy, Detva and in Komárno. Nowadays, there are three operating units of the company:

- Operating unit Modules of driving gear in Trnav, Levice and Komárno
- Operating unit Modules of damping in Levice and Šahy
- Operating unit Chassis components in Levice and Detva

Report of the internal audit

Internal audit in a production organization is made before realization of external audit of quality management system in the given organization. We can, therefore, state, that it is a kind of preparation for the external audit, which may help the organization to reveal possible errors and shortcomings. Consequently, the organization has time to eliminate these shortcomings before performing the external audit and accept potentials for improvement in the future.

After finishing the internal audit we elaborated a report from the internal audit, containing a list of auditor findings during audit. They are:

- MNC (main non conformity) – the main deviation,
- NC (non conformity)- fine deviation,
- OI- potential for improvement.

The main deviations are deviations which may, quite significantly and negatively, influence production processes and they are not in accordance with the norm, according to which the system is audited, therefore it is necessary to pay attention to them [2].

Fine deviations do not have a significant influence on processes, however these may gradually end up like the main deviations. These deviations must be watched right after the

main ones.

In table 1 we can see the report from the internal audit, displaying findings in all the branches of the production organization, showing adequate chapter of ISO IATF 16949:2016 norm, to which they belong. The findings are described by brief and clear way and they contain a place of the mismatch. The report from the audit is one of the main documents, elaborated by the main internal auditor. This document is then delivered to the quality manager of the production organization [2].

***Table 1** Report of the internal audit*

№	Finding	Evaluation
1	Géňa: There is no risk analysis for all the production processes (process FMEA).	MNC
2	At the department of product development there was no proof of a level of workers´ training in the area of: risk analysis, FMEA of a product, safety of a product	NC
3	Géňa: Production, a change in production. Number of production: 42953998, number of a part: 07113998, it was not presented from the quality department. Recommendation: protocol must be a part of documentation of releasing the first piece, if not, service sees that release was not performed. It is necessary to perform repetitive release in case of big production order min. 1/day.	NC
4	Levitex: Transport units on an assembly line V6 are contaminated on the outside and show significant contamination inside. There was no description of the process presented, for cleaning transport units. From the whole level of contamination, it is clear, that cleaning is not performed regularly.	NC
5	Géňa: In case of a claim no. 272 /2018, no steps D1-D3 were performed. In case, the claim was done by a supplier, a team must be created, a problem described and immediate action accepted.	NC
6	Trnava: Quality assurance: claim, number 1800784, part number: 90700004645, missing screw. In 8D programme it is stated that revision of process FMEA was not updated.	NC

Catalogue of corrective actions for the main and fine deviations

After finishing internal audit of quality management system, the head internal auditor elaborates and sends a report on internal audit to a quality manager of the organization. They must then elaborate a catalogue of corrective actions. During audit we found one main deviation, five side deviations and seven potentials for improvement. The main deviation in the internal audit was a finding in Géňa branch, saying that there was no risk analysis (process FMEA) elaborated for all production processes. The main deviation is always monitored and has a priority during elaboration of a corrective actions catalogue [2].

Preventive actions are also recorded in a catalogue of corrective actions (PA), which may help the organization in the future, to prevent deviations. For one finding, more preventive actions can be elaborated. Another part is responsibility for the given corrective and preventive actions, where a function of a worker responsible for performing these actions, is described. Moreover, even the date up to which the actions must be taken, are a part of a corrective actions catalogue as well and documents must be sent to the head auditor for approval. Corrective actions catalogue of internal audit is recorded for 3 years at the quality manager.

***Table 2** Continuation of the report from audit*

№	Finding	Evaluation
7	Levitex: Not measured effectiveness of processing complaints from 0 km (length of processing a complaint)	OI
8	Trnava: Warehouses and areas of material acceptance. It is necessary to implement 5S. In the areas behind the shelves there was a mess, scrap, a bicycle. Recommendation- to mark places determined for supplies of operating material, spare parts and series supplies.	OI
9	Various areas – problems with documentation, e.g. documents were not filled completely or not completed activities within 5S. Levitex: Incorrectly filled cart of releasing the first piece, establishment plan no. 06308255 404/234 did not meet requirements of a managed document.	OI
10	Development: information from the lessons learned must be transferred to a control list	OI
11	Trnava: checkout - nowadays 35 claims are opened, partially from 2017, comparison of the status in a SupplyOn system and SQR database.	OI
12	Maintenance: from the first sight it is not clear from the system, when the maintenance is transferred	OI
13	Trnava: On a pressing machine during production of a pump before assembly in a production of changers, there were parts placed on one transport trolley with a different level of processing. Storage places on a trolley, are not marked. Status of parts is not clear. Within repetitive insertion of a part into a machine, it can be damaged.	OI

Corrective and preventive actions for individual findings

Finding 1:

Corrective action - to process FMEA for missing production processes.

Preventive action – review of all the processes P-FMEA and review of actual state of FMEA on production branches.

Finding 2:

Corrective action – to ensure training for all the employees of a development department as for risk analysis, D-FMEA and product safety.

Preventive action - together with a human resource department add training of D-FMEA and risk analysis and product safety into a list of trainings compulsory for development employees

Finding 3:

Corrective action – in case of performing measurements on trial machines out of workplace, it is necessary to always enclose a protocol from measurement to adequate production order.

Preventive action - PO1 – retraining of workers in accordance with the local regulation DL 10-03 Q: Examinations in a production process. **PO2 –** add a control of protocol presence into a first piece card in case the measurement is performed on a meter outside the workplace.

Finding 4:

Corrective action – to check transport units as for cleanliness and congestion. If necessary, clean the transport unit or re-pack the parts to different units.

Preventive action – to define a procedure of cleaning transport units and the way of its control.

Finding 5:

Corrective action – to check claim no**.** 272. Add the missing data.

Preventive action – PO1 – to check all the claims from 2018 and if necessary add the missing data. **PO2** – to add local regulation DPL 19-01 Q and procedure by claim from a customer, caused by a supplier.

Finding 6:

Corrective action – to check claim no. RMS 1800784. To harmonize information in 8D programme with performed actions in reality.

Preventive action - PO1 – to check all the claims from 2018 and if necessary to add the missing data. **PO2 –** on a regular monthly basis take out RMS list of 8D reports, stating necessity of updating P-FMEA and check whether it was reviewed in reality.

As suggestions for improvement, we propose checkouts from corrective actions catalogue an potential actions for improvement catalogue, elaborated after internal audit of system. These are inevitable to be effectively implemented into production processes of the organization to effectively fulfil their purposes. We suggest retraining of the employees to be informed with these changes. These actions provide increasing and maintaining of quality in production processes and ability of organization to fulfil requirements of the norm, according to which the audit of a system was done. It logically results in a lower number of claims, meeting requirements of customers and decreasing internal costs on nonconforming parts.

CONCLUSION

Audit of quality management system has a significant position in an organization. The findings of the audit can significantly influence effectiveness and correctness of production processes in an organization. In case of finding big number of main deviations, we must reveal reasons and propose corrective actions for these deviations. Correctly working quality management system can widely influence quality of produced parts.

The objective of the paper was to analyse and describe a process of performing internal audit, especially audit of quality management system in a production organization for production of automobile parts and elaborate catalogue of corrective actions and catalogue of actions for potential improvement for findings. Audit of quality management system was up dated according to the ISO IATF 16949:2016 norm which must be set up if the organization wants to produce parts for automobile industry.

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Resistance of Components to Zinc Plated Against Corrosion

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Abstract: *In the article we focused on the zinc coating by galvanic zinc coating on the surface of the material for its corrosion resistance. The introduction deals with theoretical knowledge such as material selection, processing, cleaning and surface protection. The next part is devoted to the measurement of the coating thickness using an X-ray machine and corrosion test methods. The article methodology deals about galvanic zinc technologies in the acid bath as well as the technological process itself, the coating thickness tests using the Fisherscope X-RAY XDL-B X-ray apparatus, the coating thickness measurement procedure and the salt spray corrosion test in the Liebisch Labortechnik SKB 1000 AT-R corrosion chamber. The results of the work show the table and the graph of the results of the coating thickness measurements and the evaluation of the corrosion test.*

Keywords: *galvanizing, corrosion, coating, surface protection*

INTRODUCTION

The corrosion requirements claimed on the most diverse machine parts are higher every year. Without surface treatments, it is now impossible to meet these high demands. One of the most widespread methods of surface treatment is galvanizing, which forms the majority of galvanically protected metals [1, 3]. The largest customer in the galvanic industry is the automotive industry, which is largely responsible for the development and innovation of galvanizing. The priority of the automotive industry is to protect components from corrosion under acceptable economic conditions. Just because of the economic reasons, the automotive industry was forced to move from the more expensive corrosion protection systems, with copper and chromium, to a cheaper galvanizing system, saving large sums of money [2]. The article emphasizes the quality of advance preparation of the surface of the components, closer analysis of the galvanic zinc technology, testing of the coating thickness application on the material surface and the tests in the corrosion chamber [5, 7].

MATERIALS AND METHODS

The aim of the article is to acquire new knowledge of the zinc coating application, to bring the zinc coating to the surface of the material by galvanizing and to check the thickness of the zinc layer using the X-RAY Fisherscope XDL-B X-ray unit whether it fulfill the demands of customer. Another objective is to determine the corrosion resistance of the deposited layer by performing a corrosion test in the Liebisch Labortechnik SKB 1000 A-TR corrosion chamber and to check the surface for compliance with the required corrosion resistance. The last part is an overall evaluation of the results of the control of the applied zinc layer thickness and the corrosion test.

Technological process of galvanic zinc coating

The surface of the components supplied for galvanizing is almost always unsuitable for direct coating. This is caused by stuck dirt on the surface, oil residues, corrosion and many other foreign substances and bodies. This surface impurity must be removed because it would make it impossible to produce a high-quality zinc coating with good adhesion to the base material. This is achieved by a sequence of several technological operations: coarse degreasing, pickling, electrolytic degreasing and subsequent surface activation [4].

Sometimes surface machining is also included before these operations. If a perfectly clean surface is not achieved, a high-quality and even zinc coating on the surface of the material cannot then occur. In this case, the coating will have poor adhesion, uneven thickness, appearance defects and reduced corrosion resistance. After the application of zinc on the surface of the material, further operations are performed to increase the corrosion resistance, i.e. passivation and painting.

The technological process itself starts with hanging the parts. The suspension is followed by a coarse chemical degreasing, which is the first stage of surface pretreatment. Coarse chemical degreasing has the task of removing all kinds of stuck impurities from the surface of the material such as substances bound to the surface by physical absorption (grease) and also by substances bound by adhesion forces such as e.g. dust, metal chips. An important feature is also the dissolution of heteropolar compounds (inorganic salts) which are poorly soluble in organic solvents. After gross degreasing, the two-stage cold rinse is followed by clean service water and then the pickling of the components is the next step. Pickling serves to remove impurities that are bound to the surface of components by chemical bonds [6].

Typical representatives of these impurities are hydrated oxides (rust). The action of these strong acids leads to a chemical reaction to form soluble salts (Fig. 1). Most often, the steel is pickled in sulfuric acid or hydrochloric acid. The next step is to re-create the two-stage cold rinse with service water. This is followed by electrolytic degreasing, which is responsible for the highest quality degreasing of the material, so it is placed at the end.

This step is followed by a cold rinse 35 and dripping to activate the material surface. It is the removal of the last impurities (oxidation layers) that have occurred in previous operations. The final step before galvanic plating is the cold one-stage rinse with water.

The actual electrolytic zinc process is carried out in an acid bath. The bath consists of an aqueous solution of potassium chloride and dissolved zinc. Another additive is boric acid to stabilize the pH of the bath. The acidity of the bath must be between pH 5 – 5.5. This operation is only followed by operations that provide a higher surface quality. One of them is a thick layer passivation, which aims to increase the corrosion resistance of the coating. The passivation is followed by rinsing with cold water and warm air drying. The last operation is the hanging from the hinges and the storage of the parts in the shipping pallets [6].

Fig. 1 Galvanizing line

X-ray coating thickness test

Zinc coating thickness tests were performed using a Fisherscope X-RAY XDL-B X-ray apparatus. Fisherscope X-RAY XDL-B is a versatile handheld or automatic layer thickness spectrometer for protective and decorative coatings of various components. It represents another major step in the development of the proven Fisherscope X-RAY XDL-B. The device

is equipped with a standard X-ray and a fixed aperture, which is suitable for measurements on larger parts and contains a large number of filters that provide optimum conditions for various measuring applications. The device is particularly suitable for non-destructive thickness measurement and thin film analysis and for the measurement of mass-produced components. High speed of measurement is achieved by using a proportional counter that allows accurate and fast measurement.

The device can analyze a large range of elements, 38 up to 24 from chlorine to uranium. The X-RAY XDL-B spectrometer has excellent long-term stability, which has a major impact on less frequent instrument calibration [6].

Technological procedure for coating thickness measurement.

Prior to measuring the zinc coating thickness of the components, it was necessary to select 20 components that were subjected to surface layer thickness measurements. The components were surface treated with galvanic acid bath. The measurement is performed on a Fisherscope X-RAY XDL-B that is connected to the WinFTM program via pc. In WinFTM it is necessary to set the required measurement parameters, such as coating type, component designation and measurement time. My measurement time was 5 seconds. The next step is to place the component on the Fisherscope X-RAX XDL-B work surface. There is a red laser spot on the desktop that indicates the measurement location. The first measuring point was the center of the part and the second point of the bottom part (see Fig. XX). Subsequently, we started the measurement using a computer and after 5 seconds we saw on the screen the measured values of the coating thickness at the specified measuring points. We did this for all 20 parts. After measuring all of the components, the program printed a protocol in which all parameters of measurement and thickness were recorded [6].

Salt corrosion laboratory tests

The salt mist corrosion test is carried out according to STN EN ISO 9227 /2012 standard, which refers to corrosion tests in artificial atmospheres, namely salt fog tests. Standard STN EN ISO 9227: 2012 This International Standard specifies equipment, reagents and test procedures in neutral salt mist (NSS), in salt mist acidified with acetic acid (AASS) and in salt mist acidified with copper accelerated acetic acid (CASS) to assess corrosion resistance metallic materials with or without permanent corrosion protection. The test for neutral sodium chloride mist is used to:

- Metal and their alloys
- Metal coatings
- Conversion coatings
- Anodic oxidation coatings
- Organic coatings on metal substrates.

The corrosion test was carried out in the Liebisch Labortechnik SKB 1000 A-TR, which is produced of highly resistant laminate, thus it is resistant to all corrosive influences. Small components are made of plastic or stainless steel to ensure maximum equipment life. The chamber features an LCD, low maintenance and very low running costs, and is capable of 24-hour continuous operation 7 days a week [6].

RESULTS AND DISCUSSION

Coating Thickness Test Results

With galvanic plating the components with zinc, but also with other plating technologies, it is very difficult to achieve a uniform thickness of the metallized layer on a product of any shape. In practice, this is impossible, so tolerance aberrances are determined. In our case the customer has determined that the layer thickens should be between 11-22μm. Twenty samples were taken into the assay form two measurements using a Fisherscope X-RAY XDL-B X-ray apparatus. The first measurement point was in the enter of the component

and the second point at the bottom of the components. In the table 1 we can see the measured values. The coating thickness test was fulfilled as all values were within tolerance [6].

Table 1 *Measured values*

Assay number	Measured value (point 1) / µm	Measured value (point 2) / µm
1	14.70	21.30
2	12.20	16.90
3	18.30	17.40
4	15.80	19.40
5	14.40	17.20
6	18.50	17.50
7	13.80	15.40
8	19.80	21.10
9	17.70	18.60
10	14.40	17.10
11	11.70	12.40
12	15.70	17.50
13	20.40	18.40
14	13.10	14.10
15	19.50	20.00
16	12.80	15.90
17	12.90	13.40
18	15.70	18.90
19	11.40	15.00
20	17.50	16.40

Corrosion tests results

The corrosion test was performed in the Liebisch Labortechnik corrosion chamber of the SKB 1000 A-TR type. The procedure of the corrosion test was made according to the standard STN EN ISO 9227, which talks about corrosion tests in artificial atmospheres and salt fog tests. Five random samples were tested for corrosion testing. The customer has determined the thickness of the coating and the corrosion resistance of the components. The zinc thickness of the components should be in the range of 11-22 µm, which all randomly selected samples met. The required corrosion resistance to white corrosion was given to customers for 240 hours.

Table 2 *Results evaluation according to STN EN ISO 10 289 standard*

Time	**240 hours**
White corrosion	**non**
Red corrosion	**---**
Evaluation of appearance change	**- 10/10**
Evaluation	**approved**

Fig. 2 Test samples after 240 hours

A corrosion test performed on five random samples, the results indicates that the required corrosion resistance to white corrosion which has been assigned by the customer. White corrosion was not observed on any test sample, so we can evaluate the galvanic zinc process to be successful.

CONCLUSION

The major problem with steel parts and structures is the damage to the base material by the chemical or physical action of the environment, causing corrosion. Applying a protective layer to the base surface of the material prevents corrosion.

In the present accession, we have questioned the resistance of Zn-coated parts against corrosion. In the first part of the measurements, we measured the thickness of the layer of twenty selected samples in the center of the component and at the bottom of the component. It was determined that the layer thickness should be in the range of 11 to 22 μm. We recorded the measured values in the table and then we constructed the graph.

Consequently, the coating thickness test of twenty measured samples was fulfilled as all values were within the tolerance. In the second part of the measurements, a corrosion test was performed on five randomly selected samples. Since the zinc deposited condition of 11 to 22 μm was met on all samples, the samples could undergo a corrosion test. Customers have been provided with the condition that the parts must remain in the corrosion chamber for 240 hours and white corrosion must not form on the surface of the component. Since there was no white corrosion on the five production samples during the 240-hour corrosion test, this means that the test condition was satisfactory.

In the future, it will be necessary to focus mainly on how to achieve the highest quality applied surface so that the applied layer is as corrosion resistant as possible. Great influence on the amount of applied layer has surface roughness. Optimum roughness values should be sought so that the consumption of zinc is as small as possible and at the same time to ensure the effectiveness of corrosion protection. In the random sample selection, we found an unevenness of the thickness of the applied layer, which was created by placing the parts in the galvanizing bath.

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Resistance of Nickel-Plated Components

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Plamen Kangalov, Vladimir Krocko, Jan Zitnansky

Abstract: *The article is aimed to evaluate the surface treatment by zinc-nickel alloy coating. The primary goal was to evaluat the thickness of the applied layer and the corrosion resistance of the component. Our team have described the process of applying Zn-Ni alloy coating, the coating thickness measurement and the corrosion resistance determination procedure. Subsequently, the Fisherscope X RAY XDL-B and the Liebisch Labortechnik SKB 1000 A-TR corrosion chamber are described. Results of the surface thickness measurement are recorded in the results.*

Key words: *plating, Zn-Ni alloy coating, coating thickness*

INTRODUCTION

The engineering industry is currently one of the most important industries in the industry, mainly because the majority of machines, equipment or aids that make life easier for people has been made in the engineering industry [2].

The field of application of machine parts is very wide, so the requirements for durability, quality or resistance are different. In this period, when the market is oversaturated, manufacturers are trying to gain a competitive advantage, either by lowering the prices or by improving the quality. However, quality is the most desired item for every customer and therefore manufacturers are trying to meet customer requirements first and foremost [5,7].

Particularly important industry is the automotive industry, as Slovakia is currently one of the most important car manufacturers in Europe. That is why most mechanical engineering organizations are trying to become a partner and supplier of automotive components. Of course, the quality of the parts offered is related to this, because if the quality is not fulfilled, the customer has countless possibilities for replacement on the market [1].

The most important part of the car after the engine is the chassis, which is exposed to the most adverse weather, dirt, mud or salt. Since these weather conditions cause corrosion, it is important that the components forming the chassis part have high corrosion resistance, since damage or destruction of these parts during operation could have fatal consequences. One of the way to increase the corrosion resistance is the plating the surface of components with various metal or alloy coatings such as Zn-Ni alloy coating, which is currently widely used in the engineering industry [3,4].

MATERIALS AND METHODS

The aim was to evaluate the process of surface treatment with Zn-Ni alloy coating applied in the bath line in the following steps:

− checking the coating thickness using the Fisherscope X RAY XDL-B to determine if the measured values are within the desired range indicated by the customer,

− performing a corrosion test in the Liebisch Labortechnik SKB 1000 A-TR corrosion chamber and determining whether the corrosion resistance meets the required value,

− evaluation of the coating thickness control and corrosion test results [7].

Technological procedure of Zn-Ni alloy coating

The process of coating an alloy coating consists of several operations. The first operation is the parts hanging. After its hanging, the most important operations are followed by degreasing and cleaning. By degreasing, the surface is stripped of undesirable substances on the surface of the material. Chlorinated hydrocarbons such as tetrachloroethylene and trichlorethylene are used for degreasing. As these substances are harmful to health, the degreasing process must be carried out in a sealed facility by immersion. Degreasing is

followed by cold rinse followed by electrolytic degreasing followed by cold rinse [7].

After degreasing and cleaning, the process of activating the surface of the component follows. This operation serves to facilitate the pullout of the Zn-Ni alloy by the surface of the component and to prepare the surface before application of the respective metals, in our case zinc and nickel. In this operation, substances are added which accelerate activation and ensure equal wetting of the surface. Then the activation the Zn-Ni coating process begins. After this operation, there are only few operations to complete the process [8,10].

Coating thickness measurements procedure

From the manufacturing process, we randomly selected 20 identical parts that were surface treated with Zn-Ni alloy coating method. Using the PC, we set the required parameters for the measurement in WinFTM, as the type of surface treatment, component designation and measurement time 6 seconds. Subsequently, we put the component on the measuring board at the bottom of the Fisherscope and with the aid of a laser pointer we set the component to the desired position so the measurements were correct. Then, using PC, we started the measurement and after 6 seconds, the PC display showed the measured layer thickness and alloy composition percentages, that is the ratio of zinc to nickel in the coating layer [9].

The measured values were recorded. In this way we measured the values of all 20 selected parts.

Determination of corrosion resistance in corrosion chamber Liebisch Labortechnik SKB 1000 A-TR Corrosion test was performed according to STN EN ISO 9227 norm. This International Standard specifies equipment, reagents and test procedures in neutral salt mist, acid mist acidified with acetic acid and acid-acidified salt mist, copper-accelerated acetic to assess the corrosion resistance of metallic materials with or without corrosion protection.

The chamber is designed to simulate corrosion by alternating salt and condensation cycles to determine the resistance of prepared coatings. It is designed for automatically performed corrosion tests according to national and international standards for condensation tests and cyclic condensation tests, for salt fog tests and combined corrosion tests, including cyclic tests, often used in the automotive industry [12].

Corrosion chamber specifications:

- fiberglass construction,
- dry seal of the chest chamber lid,
- movable, freely positioning spray nozzle,
- programmable, adjustable diaphragm pumps,
- large area humidifier,
- humidity controllability in the chamber- possibility of simulation.

Procedure for the determination of corrosion resistance the test was performed according to the STN EN ISO 9227 standard, by the action of salt mist in the corrosion chamber Liebisch Labortechnik SKB 1000 A-TR. The corrosion test was done on 5 randomly selected components from the manufacturing process.

In the corrosion test, we proceeded as follows :

1. Both samples (A and B) were sufficiently labeled for easier identification during and after the test.
2. We suspended the samples and placed them in the Liebisch Labortechnik corrosion chamber and closed the chamber.
3. Subsequently, the samples were exposed to salt mist for 240 hours
4. After 240 hours, we opened the corrosion chamber and visualized both samples. We recorded the status.
5. After the visual inspection, we closed the corrosion chamber again and let the samples continue to be treated with salt spray for a further 480 hours, ie, the samples were

exposed to salt mist for a period of 720 hours, which were determined by customer.

6. After 480 hours, the samples were removed from the corrosion chamber and subjected to visual inspection again. Awe recorded the status. Both samples were tested in sald mist with NaCl solution.

RESULTS AND DISCUSSION

Measurement of the Zn-Ni Alloy Coated Coating Thickness

We have randomly selected 20 components from the manufacturing process to measure the coating thickness, where we tested the coating thickness and coating composition using the Fisherscope X RAY XDL-B, following a methodical procedure. The thickness limits of the applied thickness have been determined by the customer, ranging from 8 µm up to 15 µm. The proportion of nickel in the alloy coating should not exceed 15% , as required [13].

Table 1 *Measured values of coating thickness and composition*

Assay number	Measured coating thickness (µm)	Nickel ratio (%)	Zink ratio (%)
1	11.80	12.20	87.80
2	12.20	12.40	87.60
3	9.80	12.70	87.30
4	11.80	12.30	87.70
5	12.00	12.80	87.20
6	12.10	12.60	87.40
7	9.80	12.20	87.80
8	12.30	12.50	87.50
9	11.80	13.10	86.90
10	10.50	12.80	87.20
11	11.90	13.20	86.80
12	12.80	12.40	87.60
13	12.20	12.70	87.30
14	10.70	12.20	87.80
15	13.10	12.60	87.40
16	12,70	13.00	87.00
17	9.80	12.90	87.10
18	12.00	12.30	87.70
19	11.20	12.70	87.30
20	12.10	12.80	87.20

Measured thickness values and coating composition

Measured thickness values in micrometers (second column) and percentages of individual alloy coating components (third and fourth column).

From the measured values results, that the highest thickness of the applied layer was measured on the component number 15 and it was 13.1µm. In this layer, the nickel content was 12.6% and the zinc content was 87.4%. The second largest thickness was measured on part number 12, namely 12.8µm with a nickel content of 12.4% and zinc 87.6%.

Fig. 1 Measured component

On the other side, the smallest layer thickness was measured on part number 3 , only 9.5 μm. The proportion of nickel in this layer was 12.7% and the proportion of zinc was 87.3%, almost identical to the component on which the highest layer thickness was measured. The second smallest layer thickness was measured on part number 7 and number 17. For these components, the thickness value is 9.8μm. The proportion of nickel and zinc on part number 7 was 12.2%: 87.8%. For component No 17, it was 12.9% nickel and 87.1% zinc.

The measured values indicate that the thickness and composition of the alloy coating applied to the 20 components are different, but we can definitely say that all the components meet the condition of the coating composition and the nickel and zinc content of it, since no more than 15% was measured on either component nickel [12].

Corrosion test

The corrosion test was evaluated according to STN EN ISO 10289 /2003 norm, which describes methods of corrosion testing of metallic and other inorganic coatings on metallic substrates and on the evaluation of test samples and products subjected to corrosion tests. We followed the methodical procedure during the test.

The customer's required white corrosion resistance was set at 240h and at 720hrs for red corrosion.

The test results are recorded in Table 2 and documented in Figure 2,3,4 and 5.

From Table 2 and the accompanying photo documentation of the test samples indicate that no white or red corrosion was observed on either sample A or B after 240 hours or 720 hours.

The required corrosion resistance to white corrosion was set to 240 hours by the customer and the corrosion resistance to red corrosion to 720 hours. As none of the samples showed any of the corrosion types, we can say that the Zn-Ni alloy coating process meets the requirements set by the customer.

Table 2 *Corrosion tests results*

Assay	A2	B3	A	B
Time	240h	240h	720h	720h
White corrosion	No	No	No	No
Red corrosion	No	No	No	No

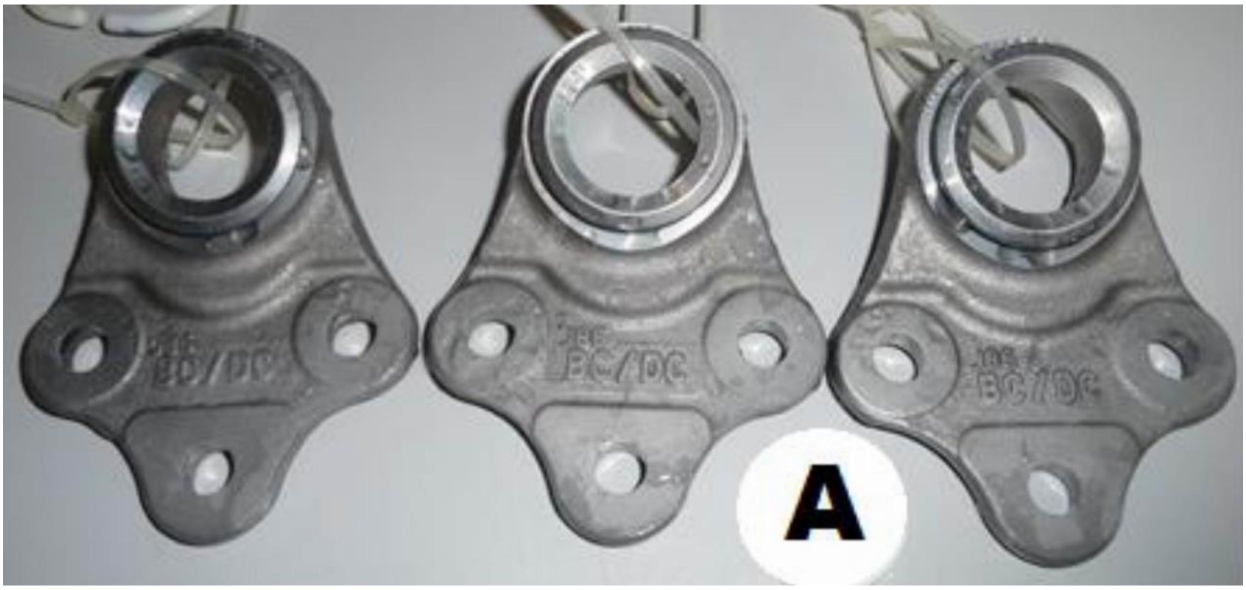

Fig. 2 Sample without heat after 240h

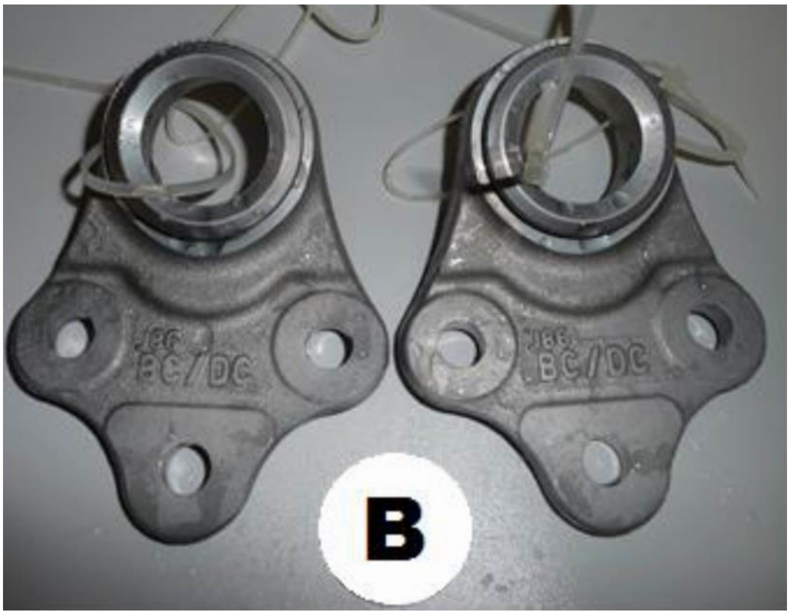

Fig. 3 The sample was heated up to 120 ° C for 24h, after 240hrs

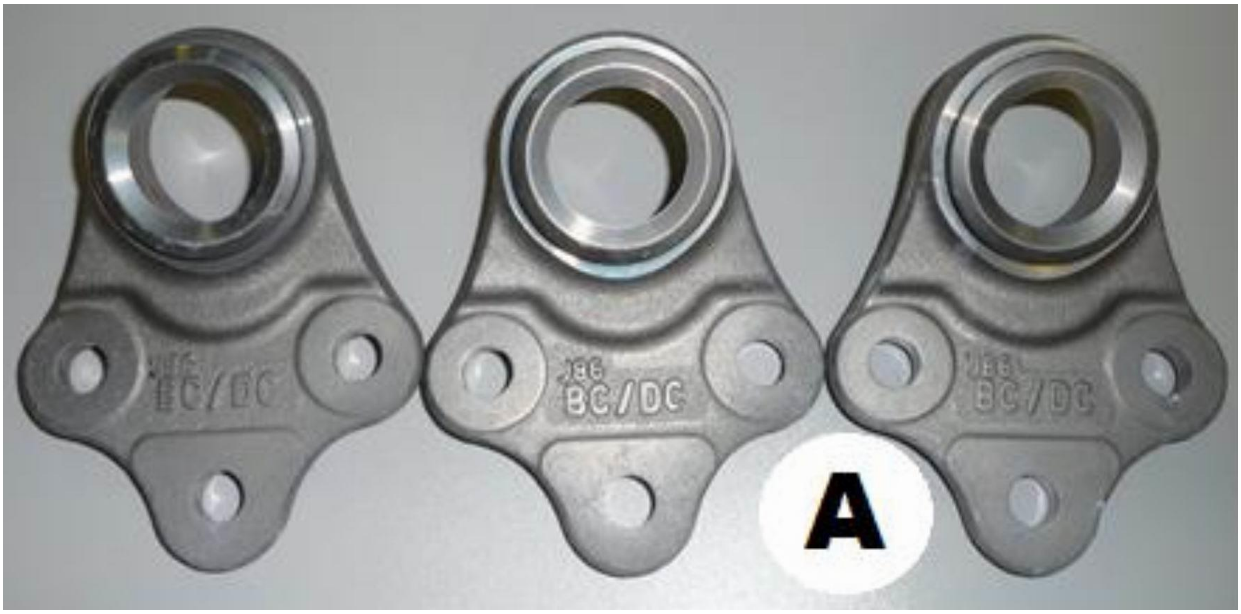

Fig. 4 Sample without heat after 720h

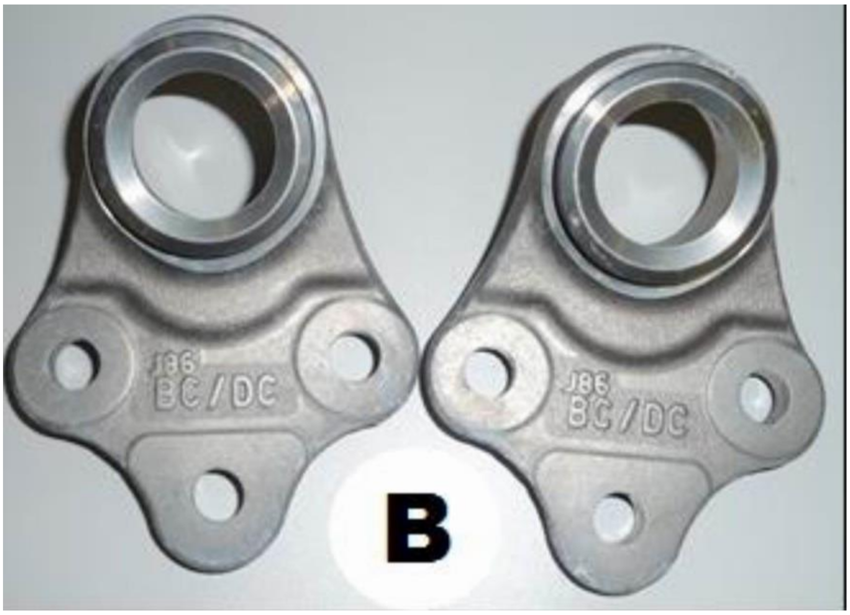

Fig. 5 The sample was heated to 120 ° C for 24h, after 720hrs.

CONCLUSION

The aim was to evaluate the process of surface treatment with Zn-Ni alloy coating, which was applied in the bath line, on the basis of methodical procedure. We carried out a coating thickness control using the Fisherscope X RAY XDL-B on 20 randomly selected components. At this check, we found that the average thickness of the coatings measured was 11.615µm. No thickness was measured on either of the measured components that would lie outside the specified range of 8 to 15µm. During this inspection we also checked the percentage of nickel and zinc in the alloy coating. The nickel ratio in either case did not exceed 15%, which also corresponds to the stated requirement. The highest layer thickness was 13.1µm. The proportion of nickel was 12.6% and the proportion of zinc was 87.4%. The smallest layer thickness was measured at 9.5µm. The nickel content of this layer was 12.7% and the zinc proportion was 87.3%. The result from the measured values that the applied

thicknesses on the different components differs, which is mainly due to the placement of the components on the hinges during the application of the alloy coating in the bath line itself. All the conditions that have been imposed by the customer, namely the thickness of the applied layer and the corrosion resistance of the components, have been fulfilled and the process of applying the Zn-Ni alloy coating is thus capable for final treatment of the components. This coating method is applicable in a variety of areas, but will certainly find its greatest application in the automotive industry, as its corrosion resistance exceeds other coatings composed, for example, of zinc alone.

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The Influence of the Deposition Rate of Application on the Thickness of the Molybdenum Layer

Marian Bujna, Plamen Kangalov, Mitko Nikolov

Abstract: *Our research was based on the requirements of practice. The production organization asked us to solve the problem of application of molybdenum layer thermal spraying. In some samples, a large thickness was measured, making it impossible to produce the product of the required parameters. The product was a molybdenum lamella for brakes and clutches. The rate of application should be constant throughout the production of the lamella. Exceeded thickness is caused by the use of a large volume of additive material. Molybdenum is a very expensive metal, which ultimately results in a financial loss. In the paper we reviewed various causes of this problem and their consequences. Based on the research, we determined that the main cause of the large thickness of the applied layer was the non-compliance with the constant molybdenum wire feed rate. We have taken corrective measures to prevent it from happening again. Linking with practice and handling manufacturers' problems is very important for our research.*

Keywords: *molybdenum layer, thermal spraying, exceeded thickness, quality production*

INTRODUCTION

Molybdenum and its alloys, and composite materials that employ molybdenum metal, provide unique combinations of thermal and electrical conductivity, thermal expansion, high-temperature strength and creep resistance, vapor pressure, environmental stability, and resistance to abrasion and wear that make them ideal (Alló et al., 2013; Votava et al., 2014).

Even though alloying increases strength, the main way molybdenum is strengthened in all cases is by mechanical deformation. This is normally done by standard rolling, swaging, and forging processes. Deformation can increase molybdenum's strength by a factor of as much as four, depending on the amount of deformation applied (Kročko et al., 2011; Paulíček et al., 2014; Paulíček et al., 2013).

Carbide-stabilized alloys contain fine particles of reactive metal carbides in the molybdenum matrix. They also benefit from a small amount of substitutional alloying conferred by the reactive metals not present as carbides and additional interstitial hardening from carbon and oxygen atoms not contained in the carbide particles. This combination maintains molybdenum's strength to temperatures higher than possible with either pure molybdenum or simple substitutional alloys because the fine particles force recovery processes to take place at higher temperatures. Processing is a key element in the success of these alloys (Kováč et al., 2014; Chantaramanee et al., 2013).

Thermal spray equipment feeds the coating material into a high-temperature jet of inert or reducing gas, which melts and atomizes the coating material and impels it onto the surface. There the droplets solidify in “splats.' building up the surface coating. The coating material source can be wire. rod. or powder. Metals, ceramics, and cermet’s are all processed using thermal spray technology. The heat source for spraying may be a flame, an electric arc. or even a controlled explosion. This variety of heat sources, carrier gases, materials, and material forms has led to the development of many different processes, including flame spray, wire spray, detonation gun deposition, high-velocity oxyfuel (HVOF) and plasma spray (Prístavka et al., 2014). The coatings themselves can be designed to impart corrosion resistance, wear resistance, friction control, and thermal insulation to the substrate. Thermal spray is also used in some cases to rebuild regions of a component that have been worn or eroded away in service (Bujna et al., 2013).

The aim of the paper is based on the requirements of the manufacturer of molybdenum lamellas. When applying the molybdenum layer to the lamella, the thickness of the layer applied was higher than that recommended, causing the part to be unusable for use and large

financial losses. Our main goal was to find out why this thickness was exceeded (Prístavka and Beloev, 2015).

MATERIALS AND METHODS

In the flame spraying process, molybdenum is fed in the form of spray wire to the spray gun where it is melted by a flammable gas. Droplets of molybdenum are sprayed onto the surface that is to be coated where they solidify to form a hard layer.

The process used is thermal spraying also known as flame spraying. Once this process is finished the final thicknesses and groove patterns are then machined to the surface to guarantee reliable friction behaviour. The following are properties that are associated with this type of material:

- good oil compatibility,
- good wear resistance,
- stable friction coefficient.

The steel lamella is coated with pure molybdenum. Thus, we can apply a thickness of 0.045 to 0.070 mm under optimal conditions.

Measurement Procedure of Prepared Samples. In case of steel parts the surface of which is covered with molybdenum, it is not required to measure the core hardness and part surface hardness. According to the technical documentation, an emphasis is on the thickness of molybdenum layer on the surface of the part. This thickness is clearly shown on the following technical drawing:

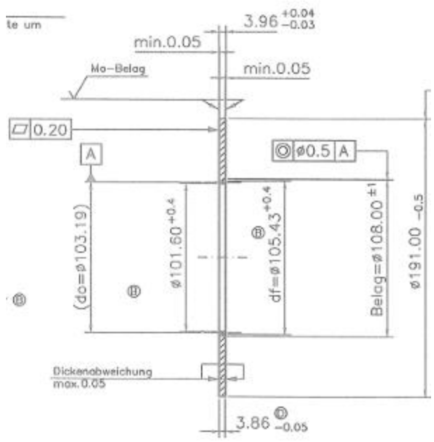

Fig. 1 The tolerance of thickness specified in the technical documentation

First of all, we prepare a sample for microscopic measurement.

Procedure of Sample Preparation.

1. Optimum implementation of sample cut from a prepared part coated with molybdenum (Furka, 2012).
2. Vertical cutting with water cooling.
3. Sample cleaning with ethanol using ultrasonic.
4. Sample drying. Preparing the SimpliMet1000 machine and the application of epovit.
5. Checking the settings of the Sipmplemet3 device.
6. Preparing the moulding press.
7. Inserting the preparation into the Ecomet3 grinder.
8. Mambo disc polishing. Taking out the samples from the preparation. Rinsing. Cleansing with cotton wool. Ethanol spraying and desiccator drying.
9. Preparing the etchant in a glass container. The etchant is a chemical compound of NH_3 and ethanol. The sample identification data is written into the database (Bujna et al., 2016; Furka, 2012; DIN EN 657:2005-06).

Using a moulding press, the sample is prepared in a way that would enable an objective observation of part surface under the microscope.

We set the microscope at 100x magnification and then choose a section on the surface that would help us to perform an analysis. Using the Leica software, we take a picture of the studied surface with an emphasis on the sample to be well lit and the picture sharp and clear. We divide the surface of a sample into 100 μm sections according to Fig. 3. Afterwards, we perform the measurement of layer thickness for every 100 μm database (Bujna et al., 2016; Furka, 2012; DIN EN 657:2005-06).

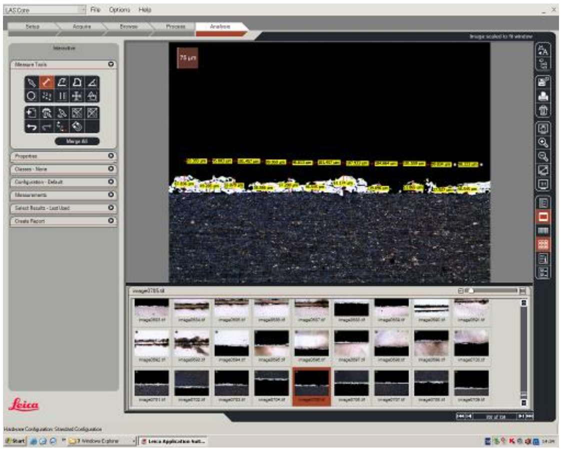

Fig. 2 The surface of studied sample divided into sections with software Leica

We calculate the average value of molybdenum on the area being examined. The resulting value should not be less than the tolerance defined in the technical documentation of the part.

RESULTS AND DISCUSSION

The task itself begins by checking the samples. The required control parameter is the thickness of the molybdenum layer applied on the steel lamella. The lamella is used in couplings for trucks, construction equipment and agricultural machinery.

The difference in the rate of application has a considerable impact on the thickness of the applied molybdenum in one part. The application process is affected by technological parameters. A technician sets the parameters for a particular part type. The part is currently undergoing a molybdenum coating process. The effect of the deposition on the molybdenum thickness is mainly ensured by the constant molybdenum wire feed rate. The wire is supplied to the nozzle and the rotational speed of the part under the nozzle, when the feed material is injected itself, is constant. The gas flow can, in exceptional cases, affect the quality or achieved thickness. The role of gases in the process is to melt the feeding wire.

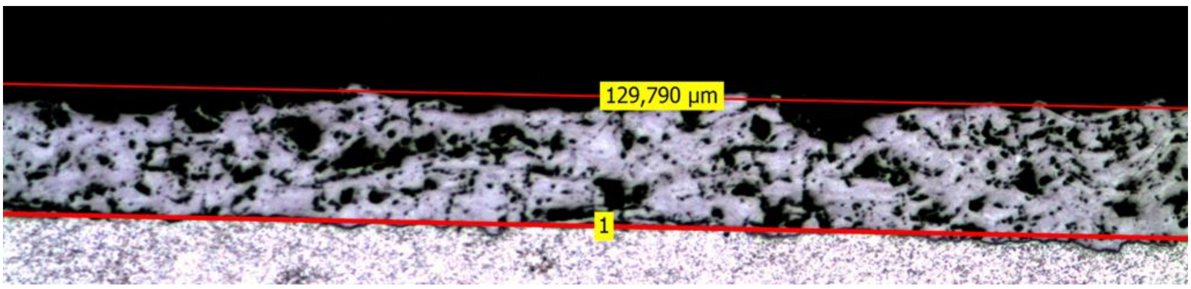

Fig. 3 Molybdenum sample No. 5 / part No. 1

Magnification: 10x10, average value: 129,790 μm

The requirement for the thickness of the applied molybdenum layer was min. 50 μm. The laboratory measurement of the sample No. 5 (Figure 3) revealed that this value was at the most critical point exceeded by 80 μm.

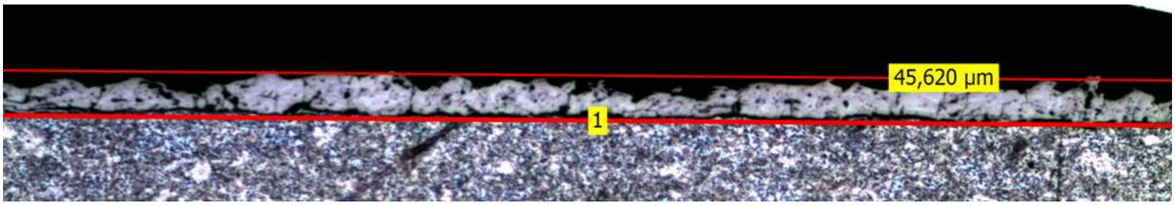

Fig. 4 Molybdenum sample No. 5 / part No. 2
Magnification: 10x10, average value: 45,620 μm

The second measurement of sample No. 5 (Fig. 4), on the other hand, showed the value of 45,620 μm, which corresponded to the values achieved during the application of this particular type of part. The follow-up consultation of our team with the internal quality engineer and the technologist was as follows. There are several causes for this anomaly when different molybdenum thicknesses of 80 μm are present on one part. They are illustrated in the table 1.

Table 1 *Analysis of unacceptable molybdenum thickness*

Problem	**Cause**	**Consequence**	**Assessment - acceptation**
molybdenum thickness of 80 μm	Incorrect attachment of the part to a rotary work table	The additional material is not applied circularly, but an elliptical movement is created.	Not accepted - it is not possible to achieve such an extreme difference in thickness
	The amount of oxygen and acetylene supplied	Exceeding the applied thickness of molybdenum	Not accepted - exceeding the thickness would be minimal
	Non-compliance with the constant speed of rotation of the parts during application	The table on which the part is placed slows down and then accelerates	Not accepted - after viewing the device
	Failure to maintain constant molybdenum wire feed rate	The wire slides through the worn-out and displaced feed wheels.	Confirmed

The problem was caused by the molybdenum wire feed rate. The wire did not move at a constant speed to the nozzle, but it slid through the worn-out feed wheels. In this case, the required layer thickness would normally not be achieved. The displaced and worn-out feed wheels have been replaced and the action has been taken to introduce a regular inspection of the equipment and its integration into the maintenance system.

The car's brake disc is a very mechanically stressed component and heats up. It must therefore be wear-resistant and have a stability of its mechanical properties at elevated temperatures. It must also be resistant to abrasion. Properties of a brake disc must comply

with prescribed mechanical properties. These properties are supplied by the applied molybdenum layer thermal spraying.

Pure molybdenum finds application as a spray coating for friction control on components in automotive, agricultural and aerospace industries. It is in this area that wire spraying is strongest, due to historical precedents and the fact that spray wire is available only as the pure metal. Journal and bearing shafts and piston rings are two major users of molybdenum coatings, applied using both wire and powder deposition processes.

CONCLUSION

The global advancement and the impact of technologies have greatly affected the field of engineering technology, which has reached a high level in recent years.

For several years this trend has been part of our Slovak engineering industry. The trend of innovations and portfolio upgrading, and thus the dispersion of processing options, has introduced the technology of molybdenum coating on steel lamellae. This has raised new questions in terms of a quality and technology, which, of course, needed concrete answers to how to ensure high quality in the shortest possible time as customer demand is high. We recorded the impacts of individual parameters on the achieved level of application quality. The results of the long-term work have achieved the desired effect.

As a result of this effort, we were able to accurately describe all the accompanying parameters and fine-tune them and thus, within a few weeks, we have achieved the parameters of the applied molybdenum layer as required by the individual technical documentation. In many cases we have saved additive material, which is very expensive.

ACKNOWLEDGEMENT

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Technological Possibilities of the Waste Recycling the Chosen Sorting Parameters Analysis

Zdenek Donoval, Robert Prochazka, Maros Korenko, Pavol Findura, Ivan Rigo

Abstract: *One of the phenomenons of the present days is the waste and its all relevant forms. This is not only because of its rising production but also of its still not employing possibilities. Waste could be called as "an unnecessary", but not "unusable", additional product of human activity. From the standard human point of view, the most significant type of waste is municipal waste. Municipal waste (MW) is an "exit product" of all of us regardless of our social status, wealth, or education. We create it in ordinary activities, at home, at work, or at school, and it is one of the few types of waste whose work we can limit by pour own responsible approach. Main aim of this paperwork was to write about existing problems with MW, open possibilities of its reduction and primarily show and present the measurement of purity, vibration and the noise as the main parameters of the modern technological form of automatic sorting process. The type of waste that was measured, was iron waste compounded in plastic waste, the detailed analyse of which is described in the paper work itself.*

Keywords: *NIR/VIS technology, optical sorting process, recycling.*

INTRODUCTION

In average in total 9.5 million tons of the waste is yearly generated in Slovakia. The biggest part of this, forms municipal waste (MW). In the year 2016, the production of MW in Slovakia was almost 1, 9 Millions of tons (348tons / citizen), the EU average MW productions / year stands for 246 Mio tons (482 tons / citizen). Also interesting parameter is the amount of the recycled MW. In spite, the recycling rate is positive, Slovakia and its neighbours still keep behind the developed leaders in the environmental market. The situation in central European market in comparison to EU average is stated bellow in table 1 .

Table 1 *Situation with MW in central EU countries vs EU average / y.2016*

EU country	MW production total	MW production Per capita	MW recycled
	Mio tons	*tons*	*%*
SK	1,89	348	23,0%
CZ	3,56	339	33,6%
HU	3,70	378	34,7%
POL	11,67	307	44,0%
ROM	4,12	208	13,3%
EU	244,86	482	45,8%

As visible from the table, compared to the EU countries, Slovakia and Czech republic belong to the countries with the lowest annual municipal waste production per capita. The average Slovak produces an average of 348 kg of municipal waste per year but segregates only 23 kg of waste (plastic, glass, paper and metal) compared to EU countries it is very low (the EU average is 111 kg).

The largest part of the waste as a whole, forms the industrial waste. About the third is generated in industrial production (ca 3 million tons per year), civil construction (1.7 million tons per year), electricity and gas supply (937-thousand tons) and supply and water purification (747-thousand tons). The long-term negative trend of the waste management in Slovakia is its disposal in landfills. The amount of waste dumped to landfills has increased from 2010 up to present at 6,2 millions of tons , that means more than 60% (65%) of all the waste produced in Slovakia is placed to landfills and up to 190 thousand tons of waste was disposed to incineration plants for combustion – with energy production or without.

Precautions of the municipal waste disposal in Landfills

There is couple of forms today to reduce the amount of MW in landfills, which include the simplest forms from decreasing the human consumption through the waste sorting, adjusting country legislative framework, up to highly sophisticated modern automatic sorting lines.

Slovakia, as an EU Member State, is strongly motivated by EU requirements to increase amount waste recycling and therefore must subsequently take measures to promote this activity and ensure efficient sorting of municipal waste by its pre-separation and collection at the centres as one of the easiest and cheapest forms of the initial phase of its disposal.

It would be helpful to efficiently separate into the specified species, with the highest possible purity and quality, so it can subsequently be used as a potential feedstock for the industry (secondary raw material, fuel, etc.) in the most efficient way. Today exist 2 main forms of separating (sorting) centres according to the volume and content of waste processed - manual or automatic.

Manual Sorting

The manual sorting centres are composed by workers (pickers) and the minimum amount of technological equipment needed (mostly simple conveyors, storage cubicles or pre-sorting grids (the oversized or undersized fractions separation). Centres are designed to separate visually identifiable waste - by color (PET bottles, oversized plastics, visible fractions such as rubber, glass, etc.) from other parts of the waste. However, they have limited sorting parameters related to the "visibility" factor as well as the quantity of the sorted waste. In general, and according to available data from existing plants of such centres, the worker is able to dispose approximately 30-40kg of distinguishable waste, which in today's waste production and its need to sort out is a poor solution.

Fig. 1 Manual sorting line (photo : www.vumz.sk)

Automatic sorting

Higher quantity (mas flow) sorting based on infra spectrum visibility to identify colour and chemical composition of the waste is currently possible only with an automatic sorting system. Optical sorting systems work on NIR principle of detection (near infrared reflection), that emits and adsorbs the reflected beam for its analyse and consequent shot-sorting by integrated pneumatics system.

To get the most efficient sorting results and pure process outcomes, full automatic sorting lines are build . The composition of such a sorting line is normally assembled with technological equipment such as:

- unpacking device (if the raw material comes in pressed packages),
- transport systems (conveyors, hopper-dump parts - transport and shipment of waste stream / flow),
- sieves (separation of over-limiting or subliminal parts of waste for further processing),
- vibration systems (uniform distribution of waste before automatic sorting),

- automatic sorting devices (so-called NIR / VIS systems),
- collection boxes with removals,
- pressing equipment (hydraulic vertical presses, pressing containers).

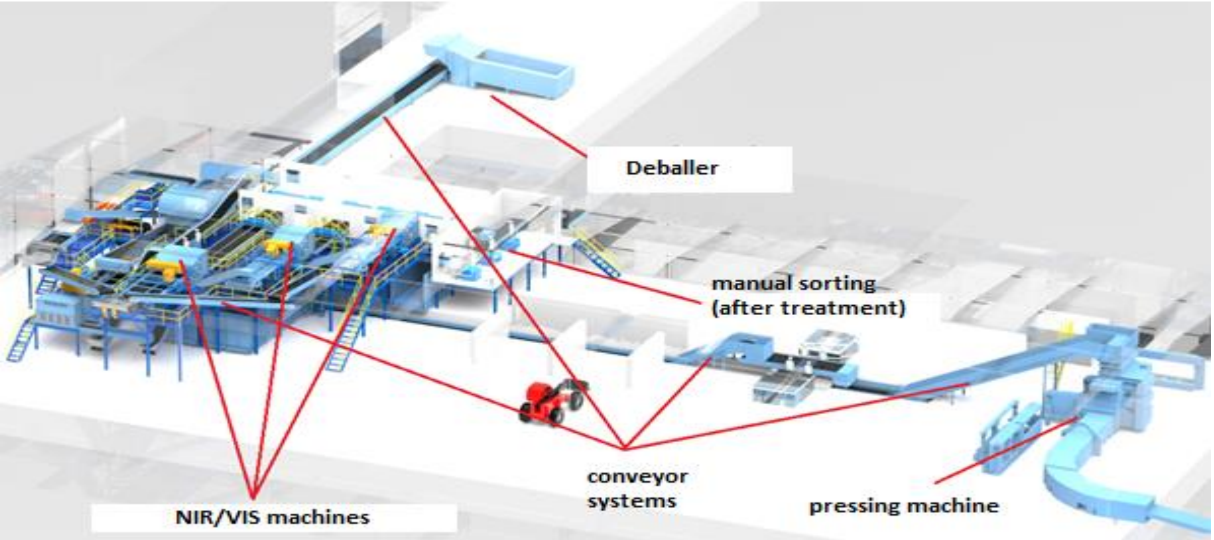


Fig. 2 Illustration of an fully automatic sorting line (source www.vumz.sk)

Automatic sorting process can be set up to the waste processing rate starting from mass flow 1 ton up to 14-15 tons/hr. These enormous figures can be increased depending on requirements of the plant. The line / separation/ speed is several times higher than manual sorting and sufficient to complete waste treatment in efficiency up to 95%.

MATERIALS AND METHODS

In the paper work we decided to look at the main parameters of the automatic sorter, that was disponible for the test in near plant, where it is produced. For the tests, the Finder type optical sorting machine was chosen, that sorts metal and non metal parts (Al, Cu) mostly. The unit was the metal waste sorting machine, 1200mm table width, belt speed up to 3.6 m / sec, EM magnetic sensors installed beneath the belt. The main parameters of the sorting were determined the mass flow rate, purity, vibrations and the noise. The type of waste analysed was the iron waste contaminated in the tested plastic waste - PET + drugstore (PP / PE) material.

For to get as authentic results as possible, we set 3 repeated measurements in 5 speed steps at 40%, 55%, 70%, 85% and 100% of the nominal belt speed .

From the taken values from the testing, the arithmetic average value was taken to eliminate deviation of the measurement itself.

Chosen formula for value determination :

$$f(average) = \left(\sum_{n=1}^{5}(a_n)\right)/n \quad , \tag{1}$$

where: *a* - is the measurement and

n - is number of test rounds (readings) taken.

Specimen batch – content :

Different PET / drugstore / material : weight 2.1 kg

Metal material: weight 3.0 kg

The conditions for separating of the sorted material were not primal, since in the production sorting line (operating plant) the sorting machine is generally placed on the platform, so that all the separated waste and outcoming residues flow in its tunnels for next processing, so that no loss is received. During the testing, the sorter stood simply on the floor

and flows were recovered in the chambers with its dropping on the workshop floor, so that little penetration was also obvious. This little problem however did not influenced the main aim of the testing – to show and demonstrate dependence of main parameters on belt speed (the real process mass flow).

To eliminate the penetration we set the deviation value 20% against 100% material collection during standard operation. The value was

$$E \;= Etest \; x \; 1{,}2 \tag{2}$$

where: E = corrected sorting purity
Etest = purity measured during testing

Fig. 3 Automatic sorting system Finder 1200 chosen for testing

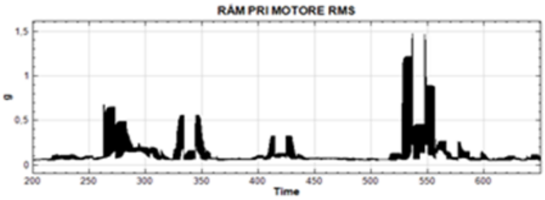
RESULTS AND DISCUSSION

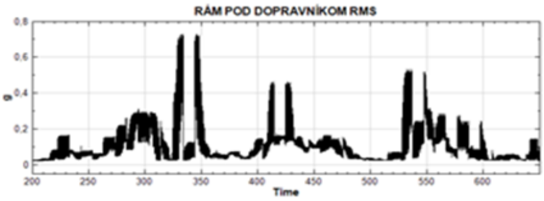
The measurements, as mentioned above, were fully aimed to show the real dependence of the main parameters of the sorting process - purity, noise and vibration levels, monitored on the various belt speed (process mass flow).

***Table 2** The main parameters of the sorting process*

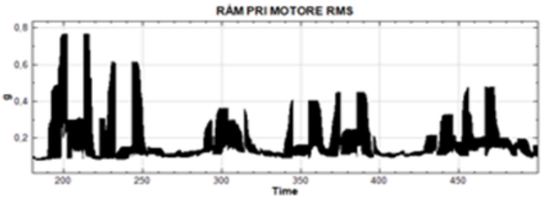
RPM				OPRTICAL SORTING	
	rpm, (m/s)			sorted stream	
				Fe	PET
		Measurement No 1		1,95	1,09
40%	1,44	Correction Fe against total quantity	1,05	2,05	1,09
		Correction to other influences	0,00	**2,46**	1,09
		Separation efficiency / contamination		82%	52%
55%	1,98	**Measurement No 2**		1,77	0,96
		Correction Fe against total quantity	1,10	1,95	0,96
		Correction to other influences	0,00	**2,34**	0,96
				78%	46%
		Measurement No 3		1,17	1,15
70%	2,52	Correction Fe against total quantity	1,09	1,28	1,15
		Correction to other influences	0,00	**1,54**	1,15
				51%	55%
85%	3,06	**Measurement No 4**		1,55	1,10
		Correction Fe against total quantity	1,07	1,66	1,10
		Correction to other influences	0,00	**1,99**	1,10
				66%	53%
100%	3,60	**Measurement No 5**		1,82	1,03
		Correction Fe against total quantity	1,07	1,95	1,03
		Correction to other influences	0,00	**2,34**	1,03
				78%	49%

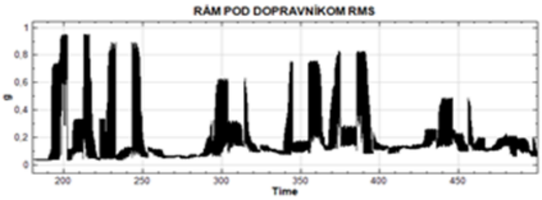
RPM		NOISE				
	rpm, (m/s)	LA	LACq	LAmax	LCpeak	
40%	1,44	67,20	88,20	98,10	111,60	dB



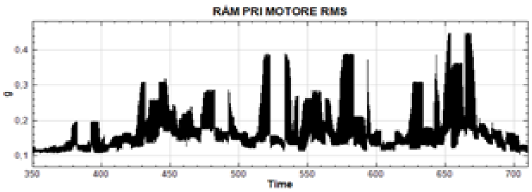


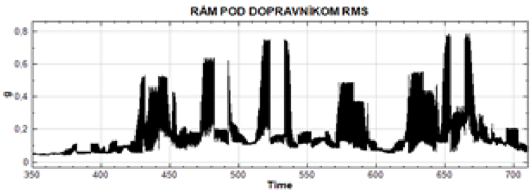
		LA	LACq	LAmax	LCpeak	
55%	1,98	70,10	93,00	98,90	112,20	dB



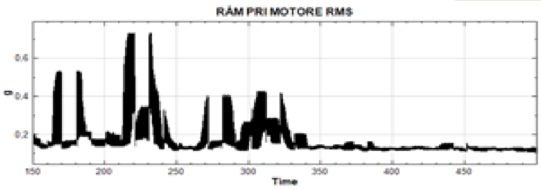


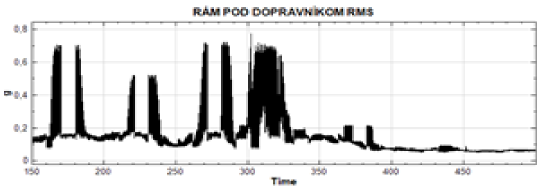
		LA	LACq	LAmax	LCpeak	
70%	2,52	66,00	92,00	99,70	111,80	dB



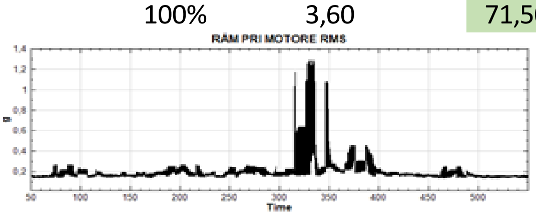


		LA	LACq	LAmax	LCpeak	
85%	3,06	72,30	96,00	101,90	113,10	dB





		LA	LACq	LAmax	LCpeak	
100%	3,60	71,50	96,00	102,80	113,50	dB



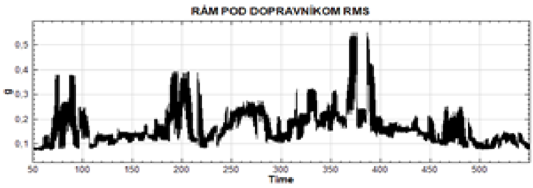


Fig. 4 Measured parameters taken against the belt speed

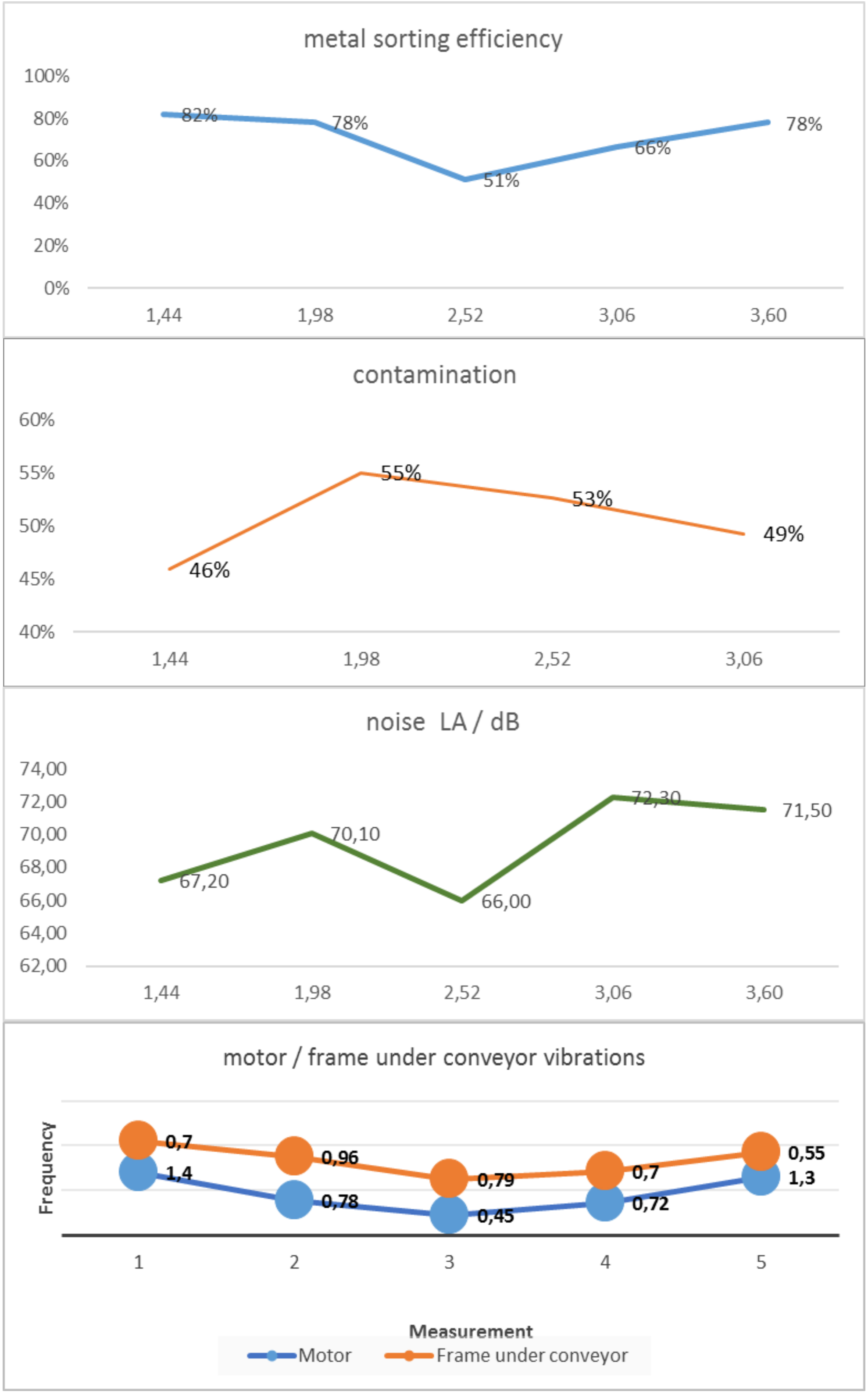


Fig. 5 Graphical illustration of the measured parameters against belt speed

CONCLUSION

The work describes problematics of the municipal waste disposal in Slovakia and neighbour countries, shows rising tendency and todays technological possibilities how to reach its eliminations against its placing into landfill. The most promising is the automatic

sorting system represented by optical, magnetic or laser sensor system. For the volume of waste processed in the best CAPEX /OPEX ratio against to the volume of technologically processed waste flow, automatic sorting appears today as the best solution. As an example was introduced the most promising system of classification using IR-based optical heads or EM integrated sensors, followed by detection and pneumatic blasting into process chambers for further processing.

The report presents the measurements taken on the Finder 1200 magnetic/optical sorting machine.

Received measurements showed the direct influence of the set drum revolutions / the belt speed / of the input conveyor. The best figures of the purity were achieved at the min and maximum speeds. However, during standard operation at 100% of the drum speed (rpm) is usually transported approximately 2 times higher material (waste mass flow).

The result clearly indicates, that best sorting results are set at a speed close to the maximum. This is happening in praxis and the technicians of the sorting machine set the units to the highest possible operating speed of the conveyor belt for obtaining best scanning and sorting results.

On the other site, the noise reached the highest value at 85% speed , a little eliminated at 100% speed. The vibrations peak was at the minimum and maximum speed. This is however set up in the operation by stabilization and compensating bars on the critical parts of the construction.

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Synthesis of Structural Schemes of Balance Mechanisms for of a Portal Crane Jib System

Iliya Todorov

Abstract: *Structural schemes for plain linkage balance mechanisms appropriate for application in a portal crane have been synthesized. The synthesis includes the following limitations: saving the configuration of the crane's mechanism used in practice; the pairs must be only of the rotating type; the mechanisms must be second class; the links must be no more than eight; the jib of the crane must make pair with the frame and must be first (guiding) for the balancing mechanism.*

Keywords*: structural synthesis; portal crane; four bar linkage; balancing mechanism; jib system.*

INTRODUCTION

The present modern portal cranes have fully- or partially- balanced jibs, which provides the same hoisting capacity for the entire range of the reach of act. There upon preserving maximum potential crane efficiency is guaranteed for the whole service space, which is a basic work demand for portal cranes [1, 2].

Another requirement for portal crane work is the provision of a horizontal moving of the cargo, for which purpose more and more perfect guiding and balancing mechanisms for structural schemes are being developed for the jib system [3, 4, 5, 6, 7].

Several diagrams are proposed, one of them shown on Fig. 1, for a full static balancing of the guiding mechanism of the jib system, which theoretically can be presented as a four bar linkage.

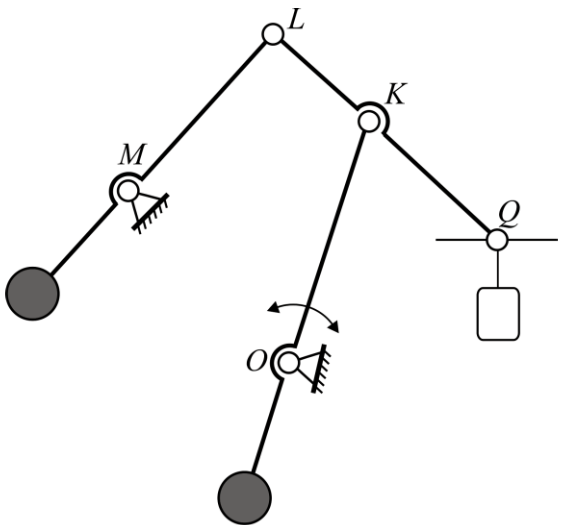


Fig. 1 Full static four bar balancing linkage

This method of balancing the portal crane guiding mechanism is unacceptable. The cause for that is the large masses of the mechanism bars, which will lead to high values of the counterweight masses.

An additional mechanism for the balancing of the portal crane guiding mechanism is used, most often – a four bar linkage – Fig. 2. One of the end bars 1* of this balancing mechanism is immovably linked to jib 1 of the guiding mechanism, and the counterweight is hanged on the other bar. A complete static balance can not be reached by using a balancing mechanism. It is approximate but is reached by a smaller counterweight mass. This mechanism can exist in two forms – parallelogramic and antiparallelogramic, presented in respectively solid and dashed lines. It is known from practice that a parallelogramic four bar linkage (Fig. 2) is mainly used as a balancing mechanism [8].

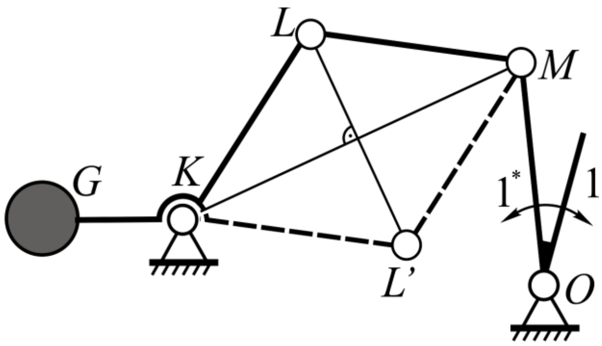


Fig. 2 Four bar balancing linkage - У$_1$

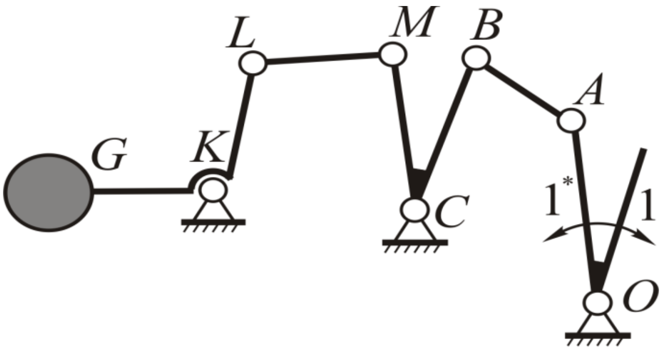


Fig. 3 Six bar balancing linkage -У$_2$

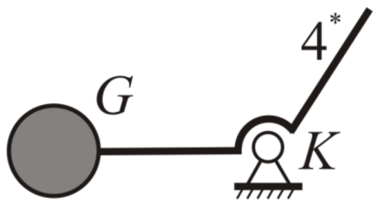


Fig. 4 Balancing linkage -У$_0$

Asix bar mechanism is known from books, shown on Fig. 3 and an eight bar mechanism as well, shown on Fig. 5 [9].

Because of its simplicity, balancing of a plain hoisting jib deserves attention – Fig.4. It can be an appropriate option for balancing mechanisms with more complicated structural schemes.

The purpose of this work is to synthesize other structural schemes of balancing mechanisms, suitable for use in portal cranes.

SYNTHESIS OF BALANCING MECHANISMS

For diminishing of large variety of schemes and guiding the structural synthesis for balancing machinery for portal crane towards desire result are initiated following limits:

a) Keeping the shape of the mechanism that is mostly used in practice – for to be stressed the applied characteristic of those who were synthesize structural schemes;

b) The new structural schemes have to contain only revolving pairs – due to hard loads to the crane;

c) The synthesized mechanisms to be with second class in the classification of ASSUR-ARTOBOLEVSKI, as the beginning bar 1* is connect with the jib – on facilitating projecting mechanisms;

d) The number of the bars in the synthesized structural schemes not to be more than eight – for producing practical aptitude in obtained.

The structural synthesis of planar lever mechanisms can be done in a different manner. For structural deduction on symmetrical lever mechanisms it is possible to be used for the approach exposed in [10, 11]. As other method for structural deduction can be used exposed in [12] parallel decision replacement in kinematic synthesis approach.

Disadvantage of the first method is that conformity of the limitation cannot be guaranteed c) – mechanisms of different classes are obtained, but with the second method in principle there isn't guarantee that it will exhaust all possible scenarios on structural schemes.

For having new structural schemes at balancing mechanisms we will apply the classical approach of Assur, which permits exhaust all possible scenarios on structural schemes and gives possibilities for easily observing the limits - b), c) and d). To meet the requirements for limits in b) and c), in deduction just join ASSUR GROUP (AG) with revolving pairs.

The sequence of the considered deduction we will expose by the mechanism from Fig. 5. At the bar 1 and posture we join the AG *ABC*. It is received four-bar linkage *OABC*. The second AG *DEF* is possible to join towards the received four-bar linkage in a different ways, one of which is shown on Fig.5. The received mechanism is six-bar linkage and it consist of two joint in series four-bar linkage (*OABC* и *CDEF*). The bar *KL* from the last AG we always join to the frame, and the bar *LM* towards one of the previous AG – in this case the connection is towards the bar *EF*.

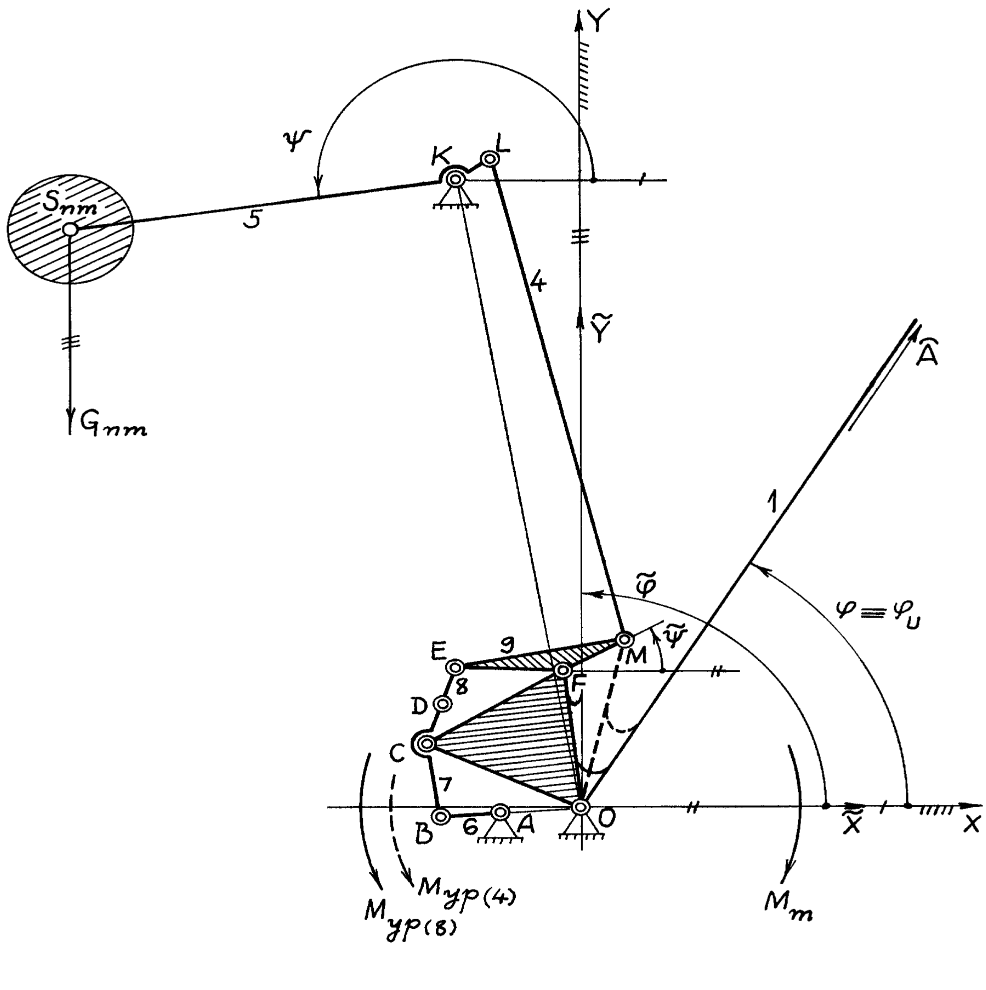
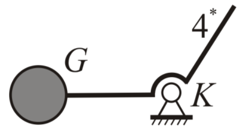
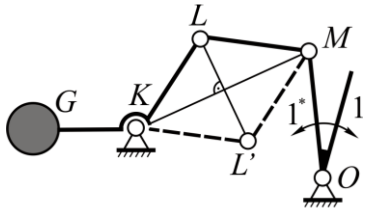
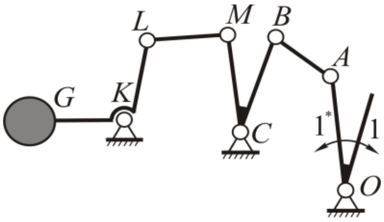
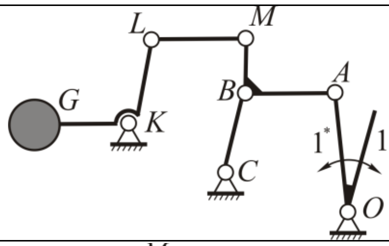
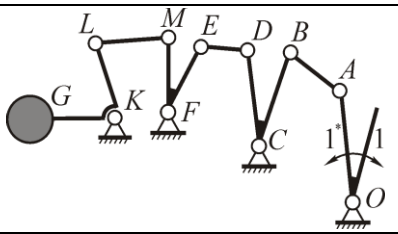
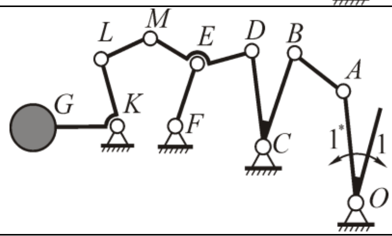
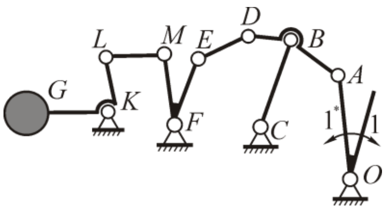
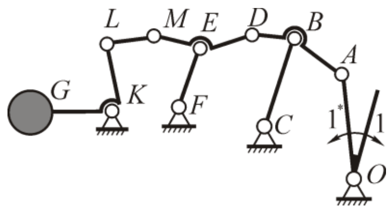
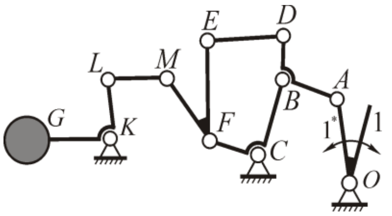
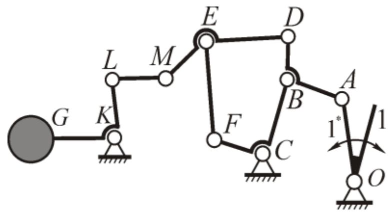
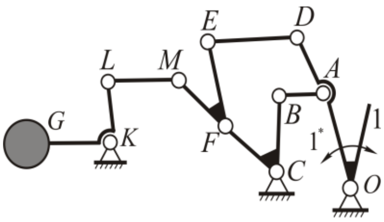
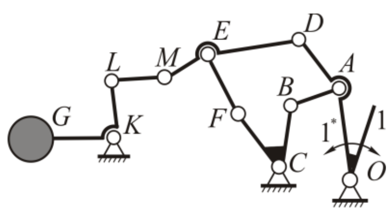
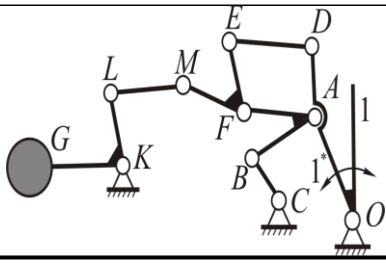
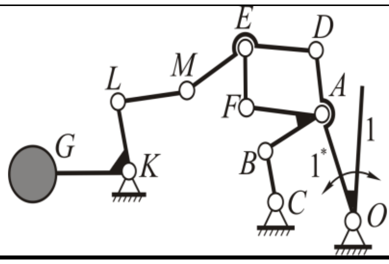


Fig. 5 Eight bar balancing linkage

Table 1 *Structural schemes of balancing mechanisms for a portal crane*

Symbol	Scheme	Number of linkage	Symbol	Scheme	Number of linkage
Y_0		2	Y_1		4
$Y_2 \equiv Y_{2,1}$		6	$Y_3 \equiv Y_{2,2}$		6
$Y_4 \equiv Y_{3,1,1}$		8	$Y_5 \equiv Y_{3,1,2}$		8
$Y_6 \equiv Y_{3,2,1}$		8	$Y_7 \equiv Y_{3,2,2}$		8
$Y_8 \equiv Y_{3,3,1}$		8	$Y_9 \equiv Y_{3,3,2}$		8
$Y_{10} \equiv Y_{3,4,1}$		8	$Y_{11} \equiv Y_{3,4,2}$		8
$Y_{12} \equiv Y_{3,5,1}$			$Y_{13} \equiv Y_{3,5,2}$		

Structural schemes of portal crane balancing mechanisms are synthesized in Table 1 along the chosen approach, all limitations regarded. It is easy to check that all of the mechanisms are of second class. In order the analysis to be thorough the already known schemes from Fig. 2, Fig. 3, and Fig. 4 are included. A symbol is used for each mechanism, the number of its bars is given. On the initial bar (the jib) is set a two-way arrow as a symbol of returning circular movement. Conditionally, for an "initial mechanism" (Yo) is assumed the balancing of the hoisting jib as well. (Fig. 4)

In the usage of the first AG, the synthesis yields the only solution Y_1 – four-bar linkage *OMLK* (Fig. 2). For the mechanisms $Y_2 \equiv Y_{2,1}$ and $Y_3 \equiv Y_{2,2}$ the second AG consists of the main bars of the balancing mechanism – the *KL* rocking arm, on which the *G* balancing counterweight and the connecting rod are hanged.

The methods of connecting the last bar LM (the rocking arm is always connected to the hinge prop) to the first AG bars are two – either to the bar *BC* of the already formed four-bar linkage *OABC* with a simple movement or to its connecting rod BA. In the two-index symbols, $Y_{2,1}$ and $Y_{2,2}$, the first index equals the number of the AG, and the second – the manner of connecting the *LM* bar from the last AG.

Now let's look into the methods of connecting the bars of the AG after the first. For the Y4 to Y13 mechanisms, after the first AG, two more AG are connected consecutively, the last of which is MLK with the G counterweight. The bars of the second AG can be connected to the four bar linkage OABC in six manners [8]:

1. To the hinge prop and the *BC* bar – thus $Y_4 \equiv Y_{3,1,1}$ and $Y_5 \equiv Y_{3,1,2}$ mechanisms are formed;
2. To the hinge prop and the *BA* connecting rod – Y_6 and Y_7;
3. To the *BC* bar and the *BA* connecting rod – Y_8 and Y_9;
4. To the 1* initial bar and the *BA* connecting rod – Y_{10} and Y_{11};
5. To the *BC* bar and the 1* initial bar – Y_{12} and Y_{13};
6. To the hinge prop and the 1* initial bar – this method does not lead to new mechanisms, because in this way the first AG loses its functionality and the thus formed mechanisms will act as Y_2 and Y_3. In the three-index symbols ($Y_{3,1,1}$ and $Y_{3,1,2}$ etc) the first index equals the number of the AG, the second – the method of connecting the second AG and the third – the manner of connecting the *LM* bar from the last AG.

The number of the balancing mechanism schemes is 14. When we additionally take into consideration the „anti-parallelogramacity" variation and the possibility of its combining with "parallelogramacity", the structural scheme number becomes 46.

CONCLUSION

In this work we synthesized the structural schemes of portal crane balancing mechanisms, which satisfy the imposed limitations. The limitations are strong, so the number of the formed schemes is not high, but if we reduce some of them, their number will possibly grow considerably. The synthesized schemes can be used to perfect and modernize the jib system of portal cranes after the implementation of an optimization synthesis.

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